EVALUATION OF CABBAGE (*Brassica oleracea* L. var. *capitata*) GENOTYPES FOR COMPACTNESS AND INTERNAL TIPBURN RESISTANCE UNDER RAIN SHELTER

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Evaluation of cabbage (*Brassica oleracea* L. var. *capitata*) genotypes for compactness and internal tipburn resistance under rain shelter"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society

Place Vellanikkara

Date 6/10/2016

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INTRODUCTION

1. INTRODUCTION

Cabbage (*Brassica oleracea* L var *capitata*) belonging to the family Brassicaceae, is a cool season crop which thrives well in a relatively cool and moist climate. It is the most popular winter vegetable grown throughout India for its leafy heads, in an area around 3 85 lakh ha with a production of 85 84 lakh tones (NHB, 2016) It is mainly consumed as raw or cooked vegetable, being rich source of vitamins (A, C and K), fibre, proteins and also anti-cancer property due to the presence of "Inole-3-carbinol" (Singh *et al*, 2010) It is grown commercially in northern parts of India during winter months (November to January) for vegetable purpose

In Kerala, earlier cabbage and cauliflower were cultivated only in the high ranges of Wayanad, Idukki and Palakkad districts With the introduction of many tropical F_1 hybrids, their cultivation has spread to the plains also Studies conducted in the Department of Olericulture, College of Horticulture have revealed that cabbage can be cultivated successfully during rainy season (off-season) inside the rain shelter Thus utilizing this low cost protected cultivation technology, an additional crop of cabbage can be raised, which will fetch a premium price in the market It was also found that the ideal planting time for off-season production of cabbage inside rain shelter is 15^{th} of May But when compared to on- season, the net head weight and yield of cabbage were less during off-season The two reasons attributed to this are loose head formation and incidence of internal tip burn, which is a calcium related physiological disorder

Calcium is an essential plant nutrient needed for cell wall development or membrane integrity, which is absorbed by roots from soil via xylem and transported to shoots Calcium deficiency is rare in nature, but may occur on soils with low base saturation and high acidity It may arise when inefficient distribution of Ca occurs rather than poor Ca uptake in the developing tissues This is because Ca cannot be mobilized from older tissues of xylem and redistribute via phloem This forces the developing tissues to depend on immediate supply of Ca in the xylem, through transpiration process. Transpiration is low in enclosing tissues lacking sufficient Ca upon hypo-osmotic shock which results in structural weakness of cell walls leading to internal tipburn Crop transpiration rate which maintain the leaf and canopy temperature plays an important role in greenhouses It has been reported that the morning relative humidity inside the greenhouse increases and affects the transpiration rate of plants The increased humidity reduces the transpiration rate and this could cause calcium deficiency in the plants grown in greenhouse which affect the leaf development

Corriveau *et al* (2012) reported that the tipburn will occur at the margins of young actively growing leaves, when the demand for Ca exceeds the plant's capacity to provide the necessary Ca which finally results this disorder Foliar applications of Ca increase leaf Ca concentration as compared to control treatments and it reduce the tipburn incidence in the romaine lettuce Tipburn is a calcium related disorder leading to death of young developing leaves inside the heads Affected heads do not show external symptoms in the field unless heads are severed, and this leads to lower yield inside rain shelter during off-season This symptom was noticed in cabbage F_1 hybrid NS 43 (Kurien, 2014) There are reports that foliar sprays of calcium can control the incidence of tipburn However, soil applications of calcium generally do not prevent the occurrence of tipburn as reported by Collier and Tibbitts (1982) There are also reports that susceptibility to tipburn is genetically determined and the use of resistant cultivar is the possible way to reduce the incidence of this disorder (Rana, 2008)

Under these circumstances the present study entitled "Evaluation of cabbage (*Brassica oleracea* L var *capitata*) genotypes for compactness and internal tipburn resistance under rain shelter" was undertaken with the following objectives

1 To identify compact genotypes with high yield for rain shelter cultivation

2 To identify genotypes with internal tip burn resistance, a calcium related physiological disorder

3 To study the effect of calcium foliar application on the incidence of internal tip burn

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cabbage (*Brassica oleracea* L var *capitata*) is a popular cool season vegetable grown all over the world for its leafy or compact head It is the most popular winter vegetable grown throughout India Recently this crop has become popular in Kerala due to the availability of tropical varieties The available literature on cabbage cultivation is reviewed under the following headlines

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2 1 1 Influence of structures and systems of cultivation on cole crops

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2 1 CONSEQUENCES OF GROWING CONDITIONS ON COLE CROPS

2.1.1 Influence of structures and systems of cultivation on cole crops

Protected cultivation is found beneficial for off-season cultivation of vegetables in the plains and for breaking the seasonal barrier

Planting of cabbage cv Derbenskaya under poly tunnels during December and another cv Ditmarscher during March, recorded increased early yield of 203 1per cent and total yield of 14 8per cent (Bakhchenova, 1976)

Schenk (1980) evaluated six Chinese cabbage hybrids under glasshouse culture They observed the incidence of leaf hedge browning in the hybrids The hybrid Spring A1 was least susceptible to leaf hedge browning in comparison with other hybrids   This hybrid performed well at 17^{0}C day and 15^{0}C night temperature and also recorded the average head weight of 825g per plant

Paratore and Ruggeri (1988) reported that five cabbage cultivars were sown under greenhouse in Sicily during 10^{th} August and 7^{th} October Temperature of greenhouse was recorded at monthly intervals Those cultivars sown in August showed better performance of average head weight and leaf length as compared to October sown cultivars

According to Thakur (1994) protected cultivation was found beneficial for the production of off-season vegetables in the plains It helps to overcome from seasonal barrier and is the most profitable farm business providing higher yield per unit area of land and steady flow of income to the farmers

Growing of cabbage was under taken in plastic tunnel to protect against rains and in open field Cabbage grown under plastic tunnel showed better performance and higher yield of 1186kg per hectare than the cabbage grown in open field conditions (Santipracha and Sadoodee, 1995)

The performance of cauliflower, knol khol and cabbage under greenhouse as well as open field was studied The crop under greenhouse showed increased number of leaves, leaf length, leaf width and yield of 5 47kg/m^2, 3 16kg/m^2 and 8 55kg/m^2 of cauliflower, knol khol and cabbage respectively in comparison with open field (Agrawal *et al* , 2003)

A Chinese cabbage hybrid Shan Chunbai 1, formed a compact leafy head and was ready for harvest within 45-50 days after transplanting in the film cover The individual head weight was about 1 5-2kg (LuGang *et al*, 2003)

Pradhan *et al* (2008) evaluated cauliflower cv Dania in three seasons namely winter, summer and rainy in Darjeeling hills of West Bengal They recorded maximum plant height and higher yield of 54 79tonnes per hectare under high cost poly house in winter as compared to summer in open field conditions

Ranawana *et al* (2008) reported that cultivation of cauliflower is limited m dry areas in open field due to the incidence of pests and diseases, which results in severe yield loss This can be overcome by raising the crop in high-tech poly house with a suitable hydrophonics system

Devadas and Gopalakrishnan (2012) reported that cultivation of cauliflower and cabbage under rain shelters gave a maximum yield up to 89% and 133% respectively The off-season cultivation of tropical varieties under rain shelter in Kerala, during June-July, produced marketable curds (Anu *et al*, 2012)

2.1.2 Influence of soil nutrients and season on growth and yield of cole crops

Generally cole crops prefer well drained medium loam to sandy loam soil rich in organic matter While growing broccoli the increased plant height was recorded with increased rate of N and K application The highest net head weight was recorded when N at 150 kg ha $^{-1}$ and K at 50 kg ha $^{-1}$ were given respectively The delayed plant maturity was observed when N and K application exceeded 150 kg ha $^{-1}$ and 50 kg ha $^{-1}$ (Singh *et al*, 2000) When plant nutrients were supplied in the form of urea, diammonium phosphate and muriate of potash at 0, 40, 60, 80 and 100 per cent through fertigation, it was found that 100 per cent recommended fertilizer rates through fertigation recorded the highest yield on broccoli (Neelam and Rajput, 2003)

Reddy and Padmaja (2005) reported that when P and Zn fertilizers were added to soil in which cauliflower cv Snowball 16 was cultivated, the curd yield significantly increased with the increasing P and Zn (100 kg P ha ^{1} and 20 kg Zn ha^{-1}) Soil application of processed poultry manure at 40 t ha ^{1} along with 23 kg ha^{-1} of Mn, 38 kg ha ^{1} of Fe and 27 kg ha^{-1} of Zn before harvesting the cabbage had not expressed any micronutrient deficiency symptoms (Vimala *et al* , 2006) The soil N from the control plot was only 0 14 per cent and it was 0 17 per cent in the organic manure applied plot at 30 t ha ^{1} The soil application of organic manure (processed poultry manure) at 15 t ha ^{1} showed increased organic carbon content ranging from 1 9 to 2 3 per cent Broccoli plants fertilized with K fertilizer through fertigation recorded the maximum curd yield (35 5 %) which was higher than the broadcasting The highest K uptake was noticed in plants supplied with K fertilizer through fertigation as compared to conventional method, because adequate supply of water helped in the effective utilization of applied fertilizer (Vittal *et al* , 2006)

Vimala *et al* (2006) revealed that the leaf P content in cabbage leaves ranged from 0 34 to 0 58 per cent, when processed poultry manure was applied at the rate of 15 t ha ^{1} The head P varied from 0 44 to 0 62 per cent The P content in cabbage was above critical level of 0 35 per cent The leaf K content in the outer leaves of cabbage was higher (4 39-9.29 %) than the head K content when processed poultry manure was applied at 30 t ha^{-1} The critical leaf K concentration was 2 0 per cent Calcium content in the outer leaves of cabbage was 3 35 per cent and calcium content in the head was only 0 72 per cent The leaf Mg content of cabbage varied from 0 57 to 0 74 per cent and in the head, Mg ranged from 0 25 to 0 29 per cent The critical leaf Mg content of vegetables was 0 2 per cent (Maynard, 1979) The outer leaves of cabbage had higher B and Fe content of 38 ppm and 333 ppm respectively as compared to head B and Fe with 33 ppm and 133 ppm The critical leaf concentrations of B and Fe in the cabbage were 16 ppm and 50 ppm as reported by Vimala *et al* (2006) A cabbage cv Early Drum Head was applied with recommended NPK at the rate of 0, 50, 100, 125 and 150 per cent through fertigation Those plants supplied with 150%

recommended dose of NPK recorded the maximum head yield of 32 26 t ha^{-1} (Shinde *et al*, 2006)

Yıldırım *et al* (2007) revealed that the soil application of 275 kg ha^{-1} N and foliar spray of 1 0 % urea resulted in increased content of nutrients viz, 3 39 per cent, 0 45 per cent, 1 96 per cent, 0 71 per cent, 0 33 per cent, 184 ppm and 40 ppm respectively of N, P, K, Ca, Mg, Fe and Mn in leaves of the broccoli cultivar AG 3317 Foliar application of 0 8 % urea and soil fertilization of 275 kg ha^{-1} N for broccoli cultivar AG 3317 recorded the maximum yield of 26 267 kg ha^{-1} Ouda and Mahadeen (2008) studied the effect of organic and inorganic fertilizers on the yield of broccoli Three doses of both organic (0, 30 and 60 t ha^{-1} FYM) and inorganic fertilizers (0, 30 and 60 kg ha^{-1}) were applied to soil They concluded that application of 60 t ha^{-1} FYM and 60 kg ha^{-1} inorganic fertilizers recorded the maximum growth and yield on broccoli A study conducted by Vazque *et al* (2010) reported that application of N fertilizers through fertigation along with plastic mulch recorded the maximum yield on cauliflower as compared to control without plastic mulching

The soil pH of experimental plots ranged from7.18 to 8 21 and liming of soil increased the availability of Mn and Zn in the soil The Cu content in the soil was low and varied from 4 68 to 4 75 mg kg^{-1} of soil The critical level of copper in cabbage leaf ranged between 1 to 5 mg kg^{-1} of dry matter (Swiatkiewicz and Sady, 2010) The Zn content in cabbage ranged between 12 9 to 14 7 mg kg^{-1} dry matter The critical level of Zn in cabbage was below 15-20 mg Zn kg^{-1} The Fe concentration in the cabbage varied from 6176 to 8184 mg kg^{-1} of dry weight and the critical content of iron in cabbage leaves was 50-150 mg Fe kg^{-1} dry matter In cabbage leaf B content was above 14 ppm as reported by Marschner (1995) The boron content in the soil was low and it ranged from 3 94 to 6 02 mg kg^{-1} dry weight of cabbage leaves The critical concentrations varied from 20 to 70 mg kg^{-1} dry weight The molybdenum requirement by the plant was lower than the other mineral nutrients The critical deficiency levels of Mo ranged from 0 1-1 0 mg kg^{-}

$^{-1}$ and soil liming increased the Mo availability Higher Ca concentration in the soil reduced the availability of Molybdenum

The soil application of recommended dose of fertilizers 180 kg N ha $^{-1}$, 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} registered the highest wrapping leaves, head length, head breadth and plant height on cabbage as reported by Meena *et al* (2011) Application of organic sources (vermi compost 5 0 t ha $^{-1}$) along with 125 per cent recommended fertilizers (100 kg ha $^{-1}$ N, 80 kg ha^{-1} P_2O_5 and 60 kg ha $^{-1}$ K_2O) recorded the maximum growth and increased yield of sprouting broccoli (Santosh *et al*, 2012)

Acharya *et al* (2015) reported that the available nitrogen in soil before planting of broccoli was 316 10 kg ha $^{-1}$ The poultry manure applied at 2 t ha $^{-1}$ recorded the maximum available nitrogen with 369 30 kg ha $^{-1}$ after the crop harvest and the minimum value was recorded in the control plot (320 33 kg ha $^{-1}$) The available potassium in the soil before planting was 162 60 kg ha $^{-1}$ The maximum available potassium 220 30 kg ha $^{-1}$ was in poultry manure applied plots as compared to control plots with 167 06 kg ha^{-1} after the crop harvest Similarly the highest available phosphorus (132 1 kg ha^{-1}) was recorded with poultry manure and it was minimum in control (90 11 kg ha^{-1}) when compared to the initial available phosphorus before planting (86 21 kg ha $^{-1}$) The initial pH value of broccoli grown soil before applying any manure and fertilizer was slightly acidic with 6 34 After harvesting the crop pH value was 7 5 in FYM (20 t ha $^{-1}$) applied plots and minimum pH value (6 51) was recorded in control The initial organic matter in the soil before planting broccoli was 1 60 per cent and after harvest the maximum organic matter content was in soil in which FYM was applied (3 99 %) and it was minimum in the control plot with 1.75 per cent

Cabbage cultivars like Castello and Bartolo were grown in open field during 15th May, 15th June and 15th July The planting time of mid-July was more ideal for the cv Castello with average head weight of 1kg per plant But, for the cv Bartolo mid-May was ideal with average head weight of 0 95kg per plant Late planting of both the cultivars resulted in poor head weight (DeMoel and Everaarts, 1990)

The effect of different planting dates (15th November, 30th November and 15th December) on cabbage cultivar Atlas-70 was studied High marketable yield was recorded from 30th November planting (Islam *et al*, 2002). Planting of the cabbage cv K K Cross on 25th October gave maximum plant height and head diameter per plant While 5th November planting of the cabbage cv K Y Cross gave lower plant height and head diameter (Haque *et al*, 2005) Singhal *et al* (2009) opined that time of planting and spacing strongly influence plant growth and individual curd weight of broccoli The effect of planting time and spacing on growth and yield of cabbage was studied Among three planting time with three spacings, namely 7th November planting with 60×40cm, 21st November planting with 60×45cm and December planting with 60×50cm, 21st November planting with a spacing of 60×45cm was more ideal for growth and yield of cabbage (Ullah *et al*, 2013)

Kurien (2014) studied the effect of different planting dates during off-season on cabbage yield per plot, the highest yield/plot (11 78 kg) was obtained from May 15th planting with a spacing of 60×45cm, followed by July 15th (9 36 kg) planting. The lowest yield (6 13 kg) was from the June 15th planting

Khan *et al* (2015) studied the effect of planting time, spacing and fertilizer application on cabbage cv Golden Acre They found that delayed planting resulted in increased number of leaves and decrease in head diameter Fertilizer application enhanced the number of leaves, head weight and head diameter Planting of cabbage at closer spacing of 20×40cm was recommended for higher yield

2 2 CULTIVARS

Successful cultıvation of cabbage maınly depends on selectıon of superıor hybrıds or cultıvars suıted for a partıcular regıon or clımatıc condıtıons

Thırteen Chınese cabbage cultıvars were grown under glasshouse ın Belgıum Hıgher yıeld was notıced from the cultıvars Asten (484 kg/acre), Manoko (468 kg/acre) and Marı (460 kg/acre). The average net head weıght per plant was more for cultıvars Cha-Cha (1 09 kg), Kasumı (1 04 kg) and Asten (1 kg) (Vanparys, 2000)

An experıment was conducted ın hıll areas of Karnataka wıth three cabbage F_1 hybrıds ın rabı season They recorded hıgher head dıameter for Krıshna (18 29cm), Shrıshtı (18 27cm) and Rajaranı (18 07cm) The hıgher yıeld was recorded from Krıshna (71 08t/ha) and lower yıeld from Rajaranı (68 92t/ha) (Rajanna and Shıvashankar, 2012)

Suseela (2008) studıed the performance of cabbage varıetıes *vız*, NS 43, NS 183 and Gaurav ın the greenhouse as well as ın open field These varıetıes gave hıgher yıeld ın greenhouse as compared to open field Pandey *et al* (2008) evaluated the cabbage hybrıd DARL-801 ın hılly areas of Uttaranchal They found that DARL-801 was early maturıng (65 5 days) wıth round compact heads of average head weıght of 2 35kg per plant

Pradeepkumar and George (2009) reported that cabbage hybrıds Harı Ranı Gol and Quısto performed well ın the open field ın central plaıns of Kerala durıng wınter season (October-March) Malu (2011) evaluated four cabbage F_1 hybrıds namely, NS 183, NS 43, NS 35 and Dısha durıng off-season (July-October) under raın shelter as well as ın open field Among these hybrids NS 43 was found ıdeal for cultıvatıon ınsıde raın shelter ın central plaıns of Kerala

2 3 IMPACT OF CLIMATE AND WEATHER CONDITIONS ON COLE CROPS

2.3.1 Temperature

The growers in Netherlands commonly practice the process of lowering temperature in greenhouse grown Chinese cabbage at head development stage and there is a correlation between tip burn incidence and lowering the temperature (Van Berkel, 1988) In tropical and subtropical regions, the production of cabbage, Chinese cabbage and lettuce is more problematic, because of higher incidence of tip burn during hot summer months (Kao and Wu, 1992)

The heat tolerant cultivar of cauliflower when grown late, with low temperature resulted in the formation of small button like curds without any proper vegetative growth (Hazra and Som, 1999) Kanwar (2001) suggested that optimum temperature for cabbage seed germination is 12-16^{0}C and for head initiation 15-20^{0}C Young seedlings have the capacity to tolerate lower temperature or frost Development of tropical F_1 hybrids has made it possible to grow cabbages above 25^{0}C temperature in the plains

Early maturing cauliflower varieties when grown well during September to October at a temperature range of 20°C to 25°C and in December to January at 5°C to 10°C The optimum monthly temperature for curd formation was 15-22°C If higher temperature coincides with curd maturity it will result in defective curds and deteriorates quality of curds (Singh, 2007)

Gopalakrishnan (2007) studied the effect of temperature and yield of early cauliflower varieties They found that when the early varieties were grown at a temperature of above 25°C, yield was 10 t/ha only with small, yellow loose curds But the yield in same cultivars increased to 12-15 t/ha at 20-25°C

2.3.2 Light

A sudden increase of sun light and dry weather after a prolonged dark condition and more humid period promoted the occurrence of tip burn (Ende, 1954). The internal tip burn incidence was not noticed under low light intensity and prolonged darkness (Thibodeau and Minotti, 1969).

Total daily sunshine hours and longer photoperiods induces higher tip burn as compared to higher light intensities (Koontz and Prince, 1986). When cabbages were grown in greenhouses they showed earlier symptom of tip burn than the open field grown cabbages, even though the greenhouse crop receive only half of the total amount of light as compared to the latter (Barta and Tibbitts, 1991). An increased light intensity and photoperiod, accelerate the tip burn incidence and its severity (Gaudreaü *et al.,* 1994). A higher temperature and sun light associated with curd development stage of cauliflower affect the curd quality and formation of yellow curds (Jaya *et al.,* 2002).

The plants grown in open field are smaller than the plants grown under rain shelter as they receive lower light in the protected structures which results in the increase in plant height (Capuno *et al.*, 2009). The yellowing of curd was noticed in cauliflower when there was direct exposure to sun light. Uncovered curds showed discoloration with loose curds. It was due to inactivation of peroxidase enzymes in the curds (Masarirambi *et al.*, 2011).

2.3.3 Humidity

Thibodeau and Minotti (1969) reported that increased tipburn incidence was positively correlated with increased temperature and relative humidity. The effect of high relative humidity in the night minimize transpiration rate and shows lower incidence of tipburn in cabbage and lettuce (Palzkill *et al.,* 1976).

Physiological processes like transpiration, water balance, ion translocation and transpirational cooling in greenhouse grown vegetables were influenced by the important environmental factor, relative humidity (Bakker, 1989).

Stamps (1994) ascertained that relative humidity was higher inside the protected structures as related to the outside environment. This is mainly because of loss of water through transpiration by plants under protected structures.

Chatterjee and Kabir (2002) observed that increased incidence of riceyness in cauliflower cultivars was positively correlated with high relative humidity. An experiment conducted by Ajithkumar (2005) revealed that days taken for the completion of vegetative stage in cauliflower was negatively correlated with the mid-day relative humidity.

2.4 INTERNAL TIP BURN INCIDENCE

Calcium deficiency is related to the inability of the plants to translocate adequate calcium to the affected parts, even though sufficient calcium is available in soil.

Cox and Dearman (1976) revealed that under protected conditions higher growth rate is associated with restricted calcium supply from soil leading to increased risk of internal tipburn. Palzkill *et al.* (1976) reported that typical tipburn symptoms will appear when the inner leaves are developed with restricted translocation and uptake of calcium. Bengerth (1979) revealed that calcium plays an important role in plant growth and development. Calcium deficiency can cause reduction in yield and nutritional quality. This may be due to abiotic factors like elevated temperature, humidity and light intensity.

Internal tip burn is a calcium related disorder which cannot be prevented by calcium fertilization. Therefore it is very difficult to protect plants from this malady. Tip burn causes irreversible necrosis or an internal break down in the margins of young developing leaves, which is mainly due to calcium deficiency (Collier and Tibbitts, 1982).

Beckar and Bjorkman (1986) opined that in some situation the tipburn affected tissues is invaded by secondary organisms that cause soft rot (*Erwinia carotovora*). Sufficient root growth is essential for uptake of calcium. But limited root growth in Chinese cabbage affects the Ca uptake and translocation to young developing leaves, thereby leading to internal tipburn incidence (Aloni, 1986).

Kobryn (1987) reported that the lower night temperature two weeks before harvesting of Chinese cabbage resulted in complete prevention of tipburn symptoms. Berkel (1988) studied the effect of high relative humidity in the night along with calcium nitrate foliar application at 0.7 per cent which resulted in complete prevention of tipburn in Chinese cabbage. A study conducted by Imai (1990) at AVRDC, Taiwan reported that covering the outer leaves of Chinese cabbage with rice straw or with red film from transplanting to till head initiation stage along with foliar spray of citric acid and split application of liquid nitrogen helped in minimizing the tipburn.

Saure (1998) reported that internal tipburn is a physiological disorder associated with calcium deficiency, which leads to necrosis of margins of young developing leaf inside the heads in crops like cabbage (*Brassica oleracea L. var. capitata*), Brussel sprouts (*Brassica oleracea L. var. gemmifera*) and lettuce (*Lactuca sativa L.*).

In a tipburn sensitive cultivar "Herman" of butter head lettuce the appearance of tipburn symptoms were observed 40 days after planting. The percentage of tip burn affected plants was higher in early planted crop than the late planted crop. At harvest time heads were severed and examined for tipburn incidence. The short term irrigation or alternate day irrigation slightly reduced the tipburn incidence (Michael, 2005).

According to Rana (2008) tipburn disorder can be overcome by the means of growing tolerant or resistant cultivars. Rana (2008) revealed that the development of younger leaves in cabbage head without calcium, because of fixation by outer leaves resulted in the incidence of tipburn. This malady can be minimized by foliar or soil application of calcium.

Kurien (2014) reported that internal tipburn leads to death of young developing leaves inside the heads. Affected heads do not show external symptoms in the field unless heads are severed, and this leads to lower yield inside rain shelter during off-season. It was noticed in cabbage F_1 hybrid NS 43.

2.5 INCIDENCE OF PESTS AND DISEASES

2.5.1 Incidence of pests

Biotic stresses cause severe damage to cabbage inside rain shelter. This leads to reduction in yield and low quality produce and often the produce fetches lower price in the market.

Chari and Patel (1983) revealed that throughout the south eastern parts of the world cabbage was severely infested by the most devastating polyphagous pest tobacco caterpillar (*Spodoptera litura* F.). Dhamo and Jotwani (1984) reported that a rapid decrease of area under cauliflower cultivation due to the elevated incidence of insect-pests like tobacco caterpillar (*Spodoptera litura*) and diamondback moth (*Plutella xylostella* L.) which resulted in extensive reduction in economic yield.

Raju *et al.* (1993) reported increased morning humidity has positive correlation on the activity of parasitoid (*Apenteles plutellae*), but negative correlation on the pest population of cut worm (*Agrostis ipsilon*). At higher temperature conditions incidence of diamondback moth (*Plutella xylostella*) was severe on cabbage, cauliflower and brussels sprouts (Gill and Sharma 1996). Jayaraj *et al.* (1999) conducted a study on NPV (Nuclear Polyhedrosis Virus) its virulence capacity, pathogenicity, mass production and efficiency in field to control tobacco caterpillar (*Spodoptera litura*) on cabbage, cauliflower, Chinese cabbage, groundnut and sunflower.

Renewick (2002) revealed that cabbage crop infested by diamondback moth (*Plutella xylostella* L.) was effectively minimized by growing of trap crops like Indian mustard (*Brassica juncea* L.), yellow rocket (*Barberea vulgaris*) and collards (*B. oleracea* var. *acephala*) in the cabbage field. Attractiveness is due to the presence of glucosinolates and other volatile compounds for its selective oviposition and feeding. A study conducted at Bapatla of Andhra Pradesh revealed that, the minimum and maximum temperatures were negatively correlated with larval populations of tobacco caterpillar (*Spodoptera litura*) and diamond back moth respectively in the first cropping season of (20^{th} November - 21^{st} January) on cabbage (Rao *et al.*, 2003). Though diamondback moth ((*Plutella xylostella* L.) is reported round the year in India, its incidence is severe during the months of February to September (Lingappa *et al.*, 2004). In cole crops more than 90per cent of crop loss was caused by the most devastating pest diamondback moth ((*Plutella xylostella* L.) all over the world (Sarfraz *et al.*, 2005).

Intercropping of cabbage with mustard at a ratio of 3:1 minimized the incidence of diamond back moth (*Plutella xylostella* L.) and cabbage aphid (*Bravicoryne brasssicae*) to an extent of 51.5 per cent and 65.2 per cent respectively (Mandal and Mishra, 2009). Cabbage is a perfect host for diamond back moth and it requires an optimum temperature range between 10°C to 30°C for growth, development and reproducibility and it cannot survive when temperature goes above 35°C (Golizadeh *et al.*, 2009).

In cauliflower, aphids (*Myzus persicae*) damage was low in the last week of December. While increased temperature in the first week of March resulted in rapid raise in aphid population and again it showed decline (Yadav, 2010). Cauliflower is the better host for survival of diamond back moth than the cabbage. The high rainfall and humidity were unfavourable for the diamond back moth population (Ahmad and Ansari, 2010). The higher incidence of caterpillar on cabbage at early growth stages is associated with loose head formation, which is a disagreeable trait in cabbage (Adenji *et al.*, 2010). Slug is one of the major pest on greenhouse grown cabbage which was effectively controlled by the use of attractant traps with alimentary bait such as beer (Bunescu *et al.*, 2010). The study conducted by Bilashini and Singh (2011) revealed that increased temperature, relative humidity and rainfall had negative correlation on aphid population in cabbage and cauliflower but sunshine hours was positively correlated.

Bana *et al.* (2012) opined that early transplanting of cabbage was associated with lower incidence of aphid and diamond back moth, while late transplanting of cabbage was associated with higher incidence of pests and diseases and it resulted in lower yield. In cabbage tobacco caterpillars (*Spodoptera litura*) were controlled by application of botanicals in combination with SLNPV (*Spodoptera litura* Nuclear Polyhedrosis Virus) @250LE per hectare and neem seed kernel extract 5 per cent. There was 86.6 per cent reduction in larval population (Narasimhamurthy *et al.*, 2012). A survey conducted by Vashith *et al.* (2013) at Himachal Pradesh, reported that elevated incidence of diamondback moth (*Plutella xylostella* L.) was noticed in greenhouse grown cabbage and Chinese cabbage with a larval population ranging from 0.40 to 0.90 per plant.

Raja *et al.* (2014) at Tamil Nadu reported higher incidence of Lepidopteran (46 %) followed by Hemipteran (27 %), Coleopteran (9 %) and Orthopteran (9 %) with three different ambient temperature conditions. Ajithkumar *et al.* (2014) revealed that incidence of stem borer, leaf webber and tobacco caterpillars was lower on delayed plantings of cauliflower as compared to early plantings on 1st November, 15th November and 1st December plantings in 2011-12, whereas delayed planting on 1st December in 2010-11 recorded high incidence of diamondback moth. Kurien (2014) reported that highest pest incidence of 23.75% on July 30th planting and lowest pest incidence of 8.75% on May 15th planting. During off-season cultivation there was severe incidence of tobacco caterpillar (*Spodoptera litura*) inside rain shelter.

2.5.2 Incidence of diseases

Horiuchi and Hori (1980) reported that waterlogging in the field increases the incidence of club root (*Plasmodiophora brassicae*) over 46 per cent. Kuo and Tsay (1981) opined that when Chinese cabbage was grown under higher temperature conditions loose head formation and internal tipburn were major problems. In cabbage stem rot caused by *Pythium ultimum* was named as Pythium rot (Kikumoto 1987). In cole crops most commonly occurring diseases are black rot caused by (*Xanthomonas campestris pv. campestris*) and downy mildew caused by (*Pernospora parasitica*) (Odour *et al.,* 1996). In cauliflower hollow stem can be minimized by application of high dose of Boron and Magnesium (Batal *et al.,* 1997). Farms at lower elevations with 22-24^{0}C temperature during summer had higher black rot disease outbreak as compared to farms at higher elevations with 22-24^{0}C during summer. Apart from climatic conditions, soil with low pH (4.9) had the higher disease incidence than the soil with pH 6.5 (Alvarez and Cho, 1998).

Bora and Bhattacharyya, (2000) reported that black rot was effectively controlled by seed treatment with *Bacillus subtilis,* or seedling treatment + soil drenching respectively. Black rot (*Xanthomonas campestris* pv. *campestris*) is managed by foliar aapplication of oxytetracycline and chlortetracycline on cole crops (Bhat *et al*., 2000). A study conducted by Dohroo (2001) showed that raise in soil moisture and temperature can enhance the development of damping-off disease, which is caused by (*Pythium sp.*) in seedling nursery and increases the seedling mortality rate. Recently Pythium disease was overcome by application of antagonistic microorganisms like *Pseudomonas* spp, *Bacillus* spp. and Pythium-inhibiting substances (Moller *et al.,* 2003). The seed treatment of cauliflower cv. PSBK-1 with mancozeb 0.25per cent + streptocycline 0.01per cent for 3 hours resulted in best control of the pathogen (Jarial and Shyam, 2003).

The seed treatment of cauliflower with streptocycline at 100 ppm for 15 minutes and seedling root dip (100 ppm) for 15 minutes before transplanting resulted in 81.84 per cent disease reduction over control treatment (Beura *et al.,* 2006). The incidence of soft rot disease caused by the bacteria *Erwinia carotovora* was positively correlated with higher humidity (Singh 2007). Chuaboon and Prathuangwong (2008) reported that the treatment of cauliflower seed with *Pseudomonas fluorescens* at 1.5 OD and also 4 foliar sprays reduced the severity of black rot with 82.08 per cent.

Rop *et al.* (2009) revealed that black spot is a major disease of cabbage in Kenya, which is caused by *Alternaria brassicicola* and *Alternaria japonica* up to an extent of 64.4 per cent and 66.7 per cent respectively. The bacterial soft rot incidence was higher when cauliflower was grown in open field and it was lesser in plants grown under rain-shelter (Capuno *et al.*, 2009). Soft rot in cabbage caused by *Erwinia carotovora* a soil borne bacteria, is most severe and destructive disease noticed all over the world (Bhat *et al.*, 2010). Rapid raise in temperature and light intensity is positively correlated with occurrence of black rot disease caused by *Xanthomonas campestris* pv. *Campestris*, as reported by Prasanna (2011).

Incidence of black rot in cauliflower caused by *Xanthomonas campestris* pv. *campestris* resulted in severe yield reduction in earlier plantings in comparison with delayed plantings in 2010-11and there was no incidence during 2011-12 respectively (Ajithkumar *et al.*, 2014). Alternaria leaf spot was observed in early as well as late plantings in 2010-11, whereas it was not noticed in 2011-12 plantings. The highest soft rot incidence of 11.25 % was on June 30th planting and the lowest (3.75 %) incidence of soft rot *Erwinia carotovora* was on May 15th planting inside rain shelter (Kurien, 2014).

2.6 ECONOMICS OF CULTIVATION

The economic feasibility of cultivating cabbage main crop and ratoon crop was studied. The yield of main crop (32341 kg/ha) was higher than ratoon crop (27780 kg/ha). The total cost of cultivation of main crop was Rs. 26169.92 per hectare and for ratoon crop it was Rs. 81670.29 per hectare. The net return from ratoon crop was lower (Rs. 19612.80/ha) than the main crop (Rs. 60712.38/ha) (Mankar *et al.*, 1990). Cultivation of cabbage in high hills of Uttar Pradesh with the commercial cost and operational cost were Rs. 794/ha and Rs. 2215/ha respectively. Material cost accounted nearly 16 per cent of the total cost while the labour cost was 74 per cent (Tripathi, 1999).

Pandey *et al.* (2001) opined that the total cost of cabbage cultivation during off-season in Shimla was Rs. 34880/ha with a benefit-cost ratio of 1.4 and the maximum contribution to cost was by human labour 43.3 per cent. Gowda *et al.* (2004) reported that intercropping of cabbage and methi in rabi season had the highest land equivalent ratio than other crop combinations. Significantly higher yield was noticed in cabbage and palak than remaining crop combinations.

The total cost of cultivation of cabbage inside rain shelter during off-season was Rs. 48.30 per m^2 and in the on-season it was Rs. 47.90 per m^2. The benefit-cost ratio was higher in the on-season crop 2.66 and it was low in the off-season crop 1.14 (Malu, 2011). Cabbage F_1 hybrid Bravo was raised inside plastic tunnels during the month of mid-May. The total cost of cultivation per hectare was Rs. 47812 and gross return per hectare was Rs. 63000. The net return from one hectare cabbage was Rs. 15187. Hence cultivation of cabbage inside plastic tunnel was profitable (Jurisic *et al.*, 2013).

The total cost of cultivation of cabbage during off-season in rain shelter was Rs. 62.70 per m^2 and May 15^{th} planting gave higher benefit-cost ratio of 1.2 and it was low (0.67) on May 30^{th} planting. The construction and maintenance of structure accounted 47.87 per cent of total cost and labour charges were 42.58 per cent of the total cost of cultivation (Kurien, 2014).

Major drawback in cabbage cultivation with low productivity was due to non-adoption of improved package of practices and high yielding F_1 hybrids by the Tripura cabbage growing farmer's. There is a huge gap in yield between improved package of practices and existing farmers practice. The average yield of F_1 hybrids were (32.3 to 33.8 t/ha) under demonstration and in the farmers practice it was only 25 t/ha as they adopted low yielding traditional varieties. The net profit under demonstration was higher (Rs. 72000/ha) and it was low in the farmers practice (Rs. 42600/ha). High Benefit-cost ratio was in the improved package of practice with 3.02 than in the existing farmers practice 2.28 (Singh and Singh, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Evaluation of cabbage (*Brassica oleracea* L. var. *Capitata*) genotypes for compactness and internal tip burn resistance under rain shelter", was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during the period between May and September 2015.

The site is located at an altitude of 22.25m above mean sea level, 10^0 31'N latitude, and $76^0$13'E longitude. This area enjoys a tropical warm humid climate and receives an average rainfall of 2663 mm per year. The climatic conditions during the period of the experimentation are shown in Appendix I. The soil of the experimental plot comes under the sandy loam in texture order Ultisol, with acidic reaction. The materials used and methods followed are presented below.

3.1 RAIN SHELTER

A rain shelter with floor area of 200 m^2 was used for the study. The frame of rain shelter was constructed using G. I pipes and it was cladded with UV stabilized polythene sheet of 200 micron thickness (Plate 1).

3.2 DESIGN AND LAYOUT OF THE EXPERIMENT

The experiment was laid out in Randomized Block Design (RBD) with two replications (Plate 2) (Fig 3.1). The details of the experiment are given below.

a. Plot size: 3 m^2
b. Spacing: 60 cm × 45 cm
c. Replications: 2

Number of treatments: 24

a. Genotypes: 8
b. Ca foliar application: 3
   C_0 (0%), C_1 (0.5%), C_2 (1.5%)

R_1		R_2	
$G_5C_2R_1$	$G_3C_0R_1$	$G_6C_0R_2$	$G_1C_2R_2$
$G_2C_2R_1$	$G_5C_0R_1$	$G_3C_1R_2$	$G_2C_1R_2$
$G_7C_1R_1$	$G_2C_0R_1$	$G_4C_0R_2$	$G_8C_1R_2$
$G_6C_1R_1$	$G_4C_1R_1$	$G_6C_1R_2$	$G_7C_2R_2$
$G_7C_0R_1$	$G_8C_1R_1$	$G_5C_1R_2$	$G_3C_0R_2$
$G_1C_2R_1$	$G_4C_2R_1$	$G_3C_2R_2$	$G_1C_1R_2$
$G_6C_0R_1$	$G_5C_1R_1$	$G_8C_0R_2$	$G_4C_2R_2$
$G_4C_0R_1$	$G_1C_0R_1$	$G_2C_2R_2$	$G_7C_1R_2$
$G_2C_1R_1$	$G_3C_1R_1$	$G_8C_2R_2$	$G_2C_0R_2$
$G_6C_2R_1$	$G_8C_2R_1$	$G_1C_0R_2$	$G_4C_1R_2$
$G_1C_1R_1$	$G_3C_2R_1$	$G_6C_2R_2$	$G_5C_0R_2$
$G_7C_2R_1$	$G_8C_0R_1$	$G_5C_2R_2$	$G_7C_0R_2$

Fig 3.1 Layout of experimental plot

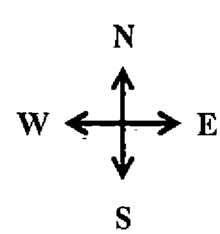

Plate 1. Rain shelter used for raising off-season cabbage

Plate 2. General view of cabbage during off-season inside rain shelter

3.3 GENOTYPES

Eight F_1 hybrids of cabbage were used for the study. As the hybrid (G_7) didn't form heads inside rain shelter, observations were recorded only from 7 hybrids. The details of F_1 hybrids used are given in (Table 3.1) (Plate 3).

3.4 SEASON

The research work was carried out during rainy (off season) season viz., May - September 2015 inside the rain shelter.

3.5 CULTURAL PRACTICES

3.5.1 Nursery practices

Cabbage seeds were sown in the plug trays filled with potting mixture of sand, soil and vermin-compost in the ratio of 1:1:1 and one month old cabbage seedlings were transplanted to rain shelter.

3.5.2 Preparation of the main field

The experimental area was cleared and then made into plots. Soil was collected from plots for pre experimental soil analysis. Ridges and furrows were taken in each plot (3 m^2). Basal application of farm yard manure was done at the rate of 25 t/ha before transplanting. One-month old seedlings were transplanted to well-prepared main field at a spacing of 60 cm × 45 cm. The field was laid out in randomized block design with two replications. There were twelve plants per treatment (Plate 4). Calcium nitrate was used as source of calcium foliar spray. Calcium nitrate at 5g/litre was used for 0.5% foliar spray (C_1) and 15g/litre for 1.5% foliar spray (C_2). In the control plot (C_0) calcium was not sprayed (Plate 5).

3.5.3 Application of fertilizers

As per the KAU package of practices fertilizer recommendation for cabbage is N: P_2O_5: K_2O 150: 100: 125 kg ha^{-1}. The Urea, Factamphos and Muriate of potash were used as source materials for supplying nutrients viz, N,

G_1 (NS 43)

G_2 (Green Challenger

G_3 (Super Ball 50)

G_4 (F_1 Border 777)

G_5 (Green Voyager)

G_6 (Mahy 118)

G_7 (Purple cabbage F_1 hybrid)

G_8 (Saint)

Plate 3. Cabbage genotypes grown during off-season inside rain shelter

Plate 4. Land preparation for raising off-season cabbage inside rain shelter

Plate 5. Calcium foliar application on cabbage during off-season inside rain shelter

P_2O_5 and K_2O respectively. These nutrients were mixed based on pre-experiment soil test report recommendation. Only 75% N, 25% P_2O_5 and 75% K_2O of KAU package of practices recommendation (KAU, 2011) were applied. Full dose of P_2O_5 and half dose of N and K_2O were applied as basal dose and remaining half dose of N and K_2O were applied one month after transplanting.

Table 3.1 List of genotypes and their source

Genotypes	Name of the genotypes	Source
G_1	NS 43	Namdhari seeds Pvt. Ltd
G_2	Green Challenger	Seminis India seeds
G_3	Super Ball- 50	Golden seeds Pvt. Ltd
G_4	F_1 border 777	Golden seeds Pvt. Ltd
G_5	Green Voyager	Sun grow seeds Pvt. Ltd
G_6	Mahy 118	Mahyco seeds Pvt. Ltd
G_7	Purple cabbage F_1 hybrid	Home garden seeds Pvt. Ltd
G_8	Saint	Seminis India seeds

3.5.4 Weeding and earthing up

Weeding and earthing up were carried out at regular intervals. Timely removal of diseased, dead and damaged plants was also carried out.

3.5.5 Plant protection

Ekalux (2ml/L) was initially sprayed for the control of flea beetle and soil drenching with *Pseudomonas fluorescens* (20 g/L) was done to control damping-off (*Pythium sp.*). The incidence of fungal rot was controlled by the application of

Mancozeb (2g/L) and Fame (1ml/L) was used for the control of tobacco caterpillar (*Spodoptera litura*).

3.5.6 Harvesting

Matured heads were harvested at marketable stage and observations were recorded.

3.6 OBSERVATIONS

Five plants were selected from each treatment for recording observations as per the description of NBPGR (Mahajan *et al.*, 2000). Both qualitative and quantitative observations were recorded.

3.6.1 Plant spread

The average distance between two outer leaves of five plants was recorded (in centi meter).

3.6.2 Number of non-wrapping leaves

The leaves that do not cover the head portion were counted at maturity stage and the mean values were taken.

3.6.3 Number of wrapping leaves

The leaves that covered head portions were counted at maturity stage and mean value was taken.

3.6.4 Days to 50% head formation

It was recorded as the number of days from transplanting to the date when 50 per cent of the plants attained head formation.

3.6.5 Days to 50% head maturity

It was recorded as the number of days from transplanting to the date when at least 50 per cent of the plants produced marketable heads.

3.6.6 Total number of marketable heads

The total number of marketable heads from each plot was recorded.

3.6.7 Head compactness

The head compactness was recorded at marketable stage as per the following scores

1. Very compact
2. Compact
3. Medium compact
4. Loose
5. Others

3.6.8 Head shape

Head shape was recorded at marketable stage as given below.

1. Flat (drum head)
2. Globe (conical)
3. Round
4. Oval

3.6.9 Head length

Head length was calculated as the average of the head length of selected heads at marketable stage and expressed in centimetre.

3.6.10 Head breadth

Head breadth was calculated as the average of the head breadth of selected heads at marketable stage and expressed in centimetre.

3.6.11 Head index

The head index was calculated as the average ratio of head length to head breadth.

3.6.12 Core length

Average length of core region of the selected heads at marketable stage was recorded and expressed in centimetre.

3.6.13 Stalk length

Stalk length was recorded at the marketable stage, as the average distance from ground level to the first non-wrapping leaves of the selected plants and expressed in centimetre.

3.6.14 Gross head weight

The weight of the heads was recorded along with a stalk of the plant and non-wrapping leaves at maturity or marketable stage (in gram).

3.6.15 Net head weight

Weights of the individual heads were taken at marketable stage (in gram).

3.6.16 Harvest index

It is the ratio of net head weight to the gross head weight taken at marketable stage.

3.6.17 Incidence of pest and diseases

Percentage incidence of major pests and diseases were recorded.

3.6.18 Yield /plot

The total net head weight of all the marketable heads from each plot was found out and expressed in kilograms.

3.6.19 Internal tip burn incidence

Percentage incidence of internal tip burn was recorded.

3.6.20 Moisture content

The moisture content of cabbage head was determined using hot air oven. A weighed sample of cabbage head was subjected to drying in hot air oven at 105^0C till consistent weight was achieved and the difference between the initial moisture content to the final moisture content was expressed in percentage.

3.6.21 Benefit: Cost ratio

The economics of cabbage crop production inside rain shelter during (off-season) was worked out. The total net return was estimated with the expected yield. The benefit: cost ratio of cabbage cultivation inside rain shelter was worked out.

3.6.21.1 Meteorological observations

Temperature, light intensity and relative humidity inside the rain shelter were recorded from transplanting to harvesting with the help of Psychrometer, Lux meter, and Digital thermometer as shown in the Appendix I.

3.6.21.2 Nutrient analysis

In the present experiment, only two genotypes were selected for soil and plant analysis. The genotype G_1 (NS 43) was susceptible to internal tipburn and G_5 (Green Voyager) was high yielding with resistance to internal tipburn. Soil analysis was done for pH, Organic carbon, available N, P, K, Ca, Mg, Fe and Mn (initial and final samples) (Table 3.2). Plant analysis for N, P, K, Ca, Mn, Mg and Fe were carried out and procedures adopted for estimation are given in (Table 3.3).

Table 3.2 Methodology followed for soil analysis

Sl. No.	Particulars	Methods	References
1	Organic carbon (%)	Wet digestion	Walkley and Black (1934)
2	Soil reaction (pH)	Photometric method using a pH meter (1:2.5 soil : water suspension)	Jackson (1958)
3	Available phosphorous (kg ha^{-1})	Extraction using Bray No. 1/ Olsen reagent and estimation calorimetrically by reduced molybdate ascorbic acid blue colour method using spectrophotometer	Bray and Kurtz (1945) Watanabe and Olsen (1965)
4	Available potassium (kg ha^{-1})	Extraction by neutral normal ammonium acetate and estimation using flame photometer	Jackson (1958)
5	Available calcium and magnesium in soil (mg kg^{-1})	Extraction by using neutral normal ammonium acetate and estimation using Atomic Absorption Spectrometry	Jackson (1958)
6	Available iron and manganese in soil (mg kg^{-1})	Extraction using 0.1M HCl and estimation by using Atomic Absorption Spectrophotometry	Sims and Johnson (1991)

Table 3.3 Methodology followed for plant analysis

Sl. No.	Particulars	Methods
1	Nitrogen content (%)	CHNS (Model: Elementars vario EL cube)
2	Phosphorus content (%)	Nitric:perchloric acid (9:4) digestion followed by filtration. Vanadomolybdate phosphoric yellow colour in nitric acid system (Piper, 1966)
3	Potassium content (%)	Nitric:perchloric acid (9:4) digestion followed by filtration. Flame photometry determination (Jackson, 1958)
4	Calcium and magnesium content (%)	Nitric:perchloric acid (9:4) digestion followed by filtration and ICP-OES determination (Piper, 1966)
5	Iron and manganese content (ppm)	Nitric:perchloric acid (9:4) digestion followed by filtration and ICP-OES determination (Piper, 1966)

3.7 Statistical analysis

Statistical analysis was done on vegetative and yield parameters of cabbage inside rain shelter by using the statistical package (OP-STAT).

RESULTS

4. RESULTS

The observations recorded on various growth and yield parameters of cabbage during the experiment was analysed statistically and the results are presented below.

4.1 Qualitative characters

4.2 Quantitative characters

4.3 Pest and disease incidence

4.4 Internal tipburn incidence

4.5 Benefit cost ratio

4.6 Soil nutrient status

4.1 QUALITATIVE CHARACTERS

4.1.1 Head compactness

Cabbage genotypes raised inside rain shelter showed variation with respect to head compactness. The genotypes G_2, G_3, G_4, G_6 and G_8 formed very compact heads in all the treatments and genotype G_1 formed loose heads in C_2 treatment, medium compact heads in control (C_0) and (C_1) treatments respectively. The genotype G_5 formed very compact heads in the (C_1) and (C_2) treatment, whereas in the control (C_0) treatment heads were compact (Table 4.1) (Plate 6).

4.1.2 Head shape

Cabbage genotypes raised inside rain shelter showed variation with regard to head shape (Plate 7). The genotypes G_2, G_3, G_4, G_5, G_6 and G_8 produced conical heads and the genotype G_1 produced round heads in all the calcium treatments (Table 4.2).

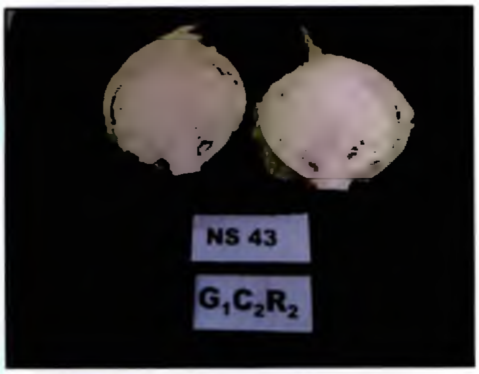

Plate 6. Head compactness of genotypes during off-season

Plate 7. Head shape of genotypes during off-season

4.2 QUANTITATIVE CHARACTERS

4.2.1 Plant spread

There was no significant difference with respect to plant spread among genotypes. However genotype G_1 recorded maximum plant spread (50.70 cm) and it was lowest in G_8 (45.10 cm). Among the different levels of calcium application maximum plant spread was in the treatment C_2 (47.50 cm) and other treatments were on par.

There was no significant interaction effect with respect to plant spread and different levels of calcium foliar application. However maximum plant spread was in G_1 C_0 (52.10 cm) and it was minimum in the G_8 C_2 (44.60 cm) (Table 4.3).

4.2.2 Number of non-wrapping leaves

There was a significant difference among cabbage genotypes with respect to number of non-wrapping leaves. The genotype G_4 recorded maximum number of non-wrapping leaves (9.26) and it was minimum (7.70) for G_8

Calcium treatments didn't show any significant difference. However maximum number of non-wrapping leaves (8.75) was noticed in the control (C_0) and it was lowest (8.37) in the (C_2) treatment. There was no significant interaction effect among the genotypes and different levels of calcium foliar application. However the lowest number of non-wrapping leaves was recorded in G_8 C_0 (7.10) and maximum (9.60) in G_4 C_1 (Table 4.4).

4.2.3 Number of wrapping leaves

There was significant effect among genotypes with respect to number of wrapping leaves. The maximum number of wrapping leaves (14.23) was in the genotype G_6 which was on par with G_3 (13.73 cm) followed by G_8 (13.03 cm) and the lowest (8.60) was in G_1.

Table 4.1 Effect of cabbage genotypes and different calcium treatments on head compactness

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**
G_1	Medium compact	Medium compact	Loose
G_2	Very compact	Very compact	Very compact
G_3	Very compact	Very compact	Very compact
G_4	Very compact	Very compact	Very compact
G_5	Compact	Very compact	Very compact
G_6	Very compact	Very compact	Very compact
G_8	Very compact	Very compact	Very compact

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50
G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118
G_8 -Saint

Table 4.2 Effect of cabbage genotypes and different calcium treatments on head shape

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)
G_1	Round	Round	Round
G_2	Conical	Conical	Conical
G_3	Conical	Conical	Conical
G_4	Conical	Conical	Conical
G_5	Conical	Conical	Conical
G_6	Conical	Conical	Conical
G_8	Conical	Conical	Conical

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50
G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118
G_8 -Saint

Different levels of calcium foliar application showed no significant effect and the control treatment (C_0) had maximum number of wrapping leaves (12.00). Interaction effect was also non-significant with respect to number of wrapping leaves. The lowest number of wrapping leaves (8.50) was in G_1 C_0 and the maximum number of wrapping leaves (14.90) was recorded in G_6 C_0 (Table 4.5).

4.2.4 Stalk length

There was significant difference among the genotypes with regard to stalk length. The mean value of stalk length was maximum (7.63 cm) in the genotype G_6 which was on par with G_3 (7.35 cm) followed by G_8, G_2, and G_1. The lowest stalk length was recorded by G_4 5.58 cm.

Calcium foliar application had no significant effect on stalk length. But the effect among genotypes and different levels of calcium foliar application was significant. The maximum stalk length (8.20 cm) was recorded in G_6 C_0, which was on par with G_3 C_0 (7.90 cm), G_2 C_1 (7.80 cm), G_6 C_2 (7.50 cm) followed by G_3 C_2 (7.35 cm), G_6 C_1 (7.20 cm), while the lowest stalk length (5.25 cm) was in G_4 C_0 (Table 4.6).

4.2.5 Days to 50% head formation

There was significant difference with respect to genotypes for days to 50 % head formation. But different calcium treatments and interaction had no significant effect. The genotype G_1 was early to form heads (59.93) and the genotype G_8 was late (65.70) which was on par with G_5 (65.16), G_4 (64.73 days), G_6 (64.70), and G_2 (63.80). However G_1 C_0 was early to form heads (59.50) and G_8 C_1 was late (66.90) to 50% head formation (Table 4.7) (Plate 8).

4.2.6 Days to 50% head maturity

Genotypes exhibited significant difference for days to 50% head maturity. The genotype G_1 was earliest (75.96) for 50% head maturity and G_4 was late (104.20) which was on par with G_8 (101.76) and G_6 (100.93). There was a no

Plate 8. Cabbage plants at head formation stage

Plate 9. Cabbage plants at head maturity stage

significant difference with different levels of calcium foliar application or interaction with genotypes. However early head maturity was registered in $G_1 C_2$ (73.80) and it was late in $G_4 C_0$ (107.50) (Table 4.8) (Plate 9).

4.2.7 Gross head weight

There was a significant difference among genotypes with respect to gross head weight. Maximum gross head weight was noticed in the genotype G_1 (1136.66 g) followed by G_5 (1005.83 g) and G_2 (1003.66 g), while the lowest was recorded in G_4 (831.66 g) (Plate 10).

Different levels of calcium foliar application had no significant effect on gross head weight. But the minimum gross head weight (926.00 g) was in the control (C_0) plot and maximum (989.85 g) was in (C_1) treatment. There was significant interaction effect among the genotypes and different levels of calcium foliar application. The maximum gross head weight (1365 g) was recorded in $G_1 C_2$, and it was minimum (790 g) in $G_4 C_1$ (Table 4.9).

4.2.8 Net head weight

Genotypes exhibited significant difference with respect to net head weight. Maximum net head weight was recorded in the genotype G_1 (787.33 g) and the minimum was in the genotype G_4 (561.00 g) followed by G_6, G_8, G_3 and G_2 respectively (Plate 10).

There was no significant difference among different levels of calcium foliar application. The maximum net head weight was registered in the treatment (C_1) with 677.14g and lowest net head weight (631.28 g) was in the control treatment (C_0). The interaction effect was also non-significant. The highest net head weight (930g) was recorded in $G_1 C_2$ and least net head weight was in G_4 C_1 of (524 g) (Table 4.10).

Gross head weight

Net head weight

Plate 10. Gross and net head weight of cabbage during off-season

Table 4.3 Effect of cabbage genotypes and different calcium treatments on plant spread (cm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	52.10	49.40	50.60	**50.70**
G_2	47.70	46.50	49.30	**47.83**
G_3	46.20	45.30	46.00	**45.83**
G_4	47.40	47.40	45.50	**46.76**
G_5	45.70	45.90	51.00	**47.53**
G_6	46.70	45.80	45.50	**46.00**
G_8	45.00	45.70	44.60	**45.10**
Mean (Treatments)	**47.25**	**46.57**	**47.50**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.4 Effect of cabbage genotypes and different calcium treatments on number of non-wrapping leaves

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	9.30	9.00	9.30	**9.20**
G_2	9.50	9.00	8.70	**9.06**
G_3	8.80	8.20	7.00	**8.00**
G_4	8.90	9.60	9.30	**9.26**
G_5	9.50	9.20	8.80	**9.16**
G_6	8.20	8.20	7.80	**8.06**
G_8	7.10	8.30	7.70	**7.70**
Mean (Treatments)	**8.75**	**8.78**	**8.37**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.65			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.5 Effect of cabbage genotypes and different calcium treatments on number of wrapping leaves

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	8.50	8.60	8.70	**8.60**
G_2	11.00	11.10	10.80	**10.96**
G_3	14.00	13.50	13.70	**13.73**
G_4	10.80	10.90	10.60	**10.76**
G_5	11.80	10.60	10.60	**11.00**
G_6	14.90	14.10	13.70	**14.23**
G_8	13.00	13.30	12.80	**13.03**
Mean (Treatments)	**12.00**	**11.72**	**11.55**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.82			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.6 Effect of cabbage genotypes and different calcium treatments on stalk length (cm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	**6.50**	7.20	5.90	**6.53**
G_2	6.25	7.80	6.45	**6.83**
G_3	7.90	6.80	7.35	**7.35**
G_4	5.25	5.90	5.60	**5.58**
G_5	5.35	6.10	5.60	**5.68**
G_6	8.20	7.20	7.50	**7.63**
G_8	6.95	7.05	6.90	**6.96**
Mean (Treatments)	**6.62**	**6.86**	**6.47**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.55			
Factor (C)	NS			
Factor (G X C)	0.95			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.7 Effect of cabbage genotypes and different calcium treatments on days to 50% head formation

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	59.50	60.10	60.20	**59.93**
G_2	65.50	62.90	63.00	**63.80**
G_3	64.80	64.30	63.40	**64.16**
G_4	64.10	66.50	63.60	**64.73**
G_5	66.80	65.20	63.50	**65.16**
G_6	64.80	63.70	65.60	**64.70**
G_8	66.70	66.90	63.50	**65.70**
Mean (Treatments)	**64.60**	**64.22**	**63.25**	
Factors	**C D ($p<0.05$)**			
Factor (G)	2.51			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.8 Effect of cabbage genotypes and different calcium treatments on days to 50% head maturity

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	76.20	77.90	73.80	**75.96**
G_2	84.80	82.60	86.50	**84.63**
G_3	87.20	88.70	90.00	**88.63**
G_4	107.50	101.00	104.10	**104.20**
G_5	94.30	83.70	79.90	**85.96**
G_6	98.00	106.80	98.00	**100.93**
G_8	102.60	102.00	100.70	**101.76**
Mean (Treatments)	**92.94**	**91.81**	**90.42**	
Factors	**C D ($p<0.05$)**			
Factor (G)	4.94			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.9 Effect of cabbage genotypes and different calcium treatments on gross head weight (g)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	935.00	1110.00	1365.00	**1136.66**
G_2	936.00	1065.00	1010.00	**1003.66**
G_3	963.00	1068.00	820.00	**950.33**
G_4	890.00	790.00	815.00	**831.66**
G_5	861.00	1055.00	1101.50	**1005.83**
G_6	985.00	951.00	892.00	**942.66**
G_8	912.00	890.00	902.50	**901.50**
Mean (Treatments)	**926.00**	**989.85**	**986.57**	
Factors	**C D ($p<0.05$)**			
Factor (G)	122.08			
Factor (C)	NS			
Factor (G X C)	211.46			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50
G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118
G_8 -Saint

Table 4.10 Effect of cabbage genotypes and different calcium treatments on net head weight (g)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	648.00	784.00	930.00	**787.33**
G_2	633.00	691.00	640.00	**654.66**
G_3	680.00	725.00	533.00	**646.00**
G_4	623.00	524.00	536.00	**561.00**
G_5	571.00	686.00	720.00	**659.00**
G_6	665.00	630.00	596.00	**630.33**
G_8	599.00	700.00	609.00	**636.00**
Mean (Treatments)	**631.28**	**677.14**	**652.00**	
Factors	**C D ($p<0.05$)**			
Factor (G)	104.60			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

4.2.9 Head length

There was no significant effect among genotypes for head length. However the genotype G_1 had the maximum head length (12.91cm) and it was lowest in the genotype G_5 (11.56 cm). Foliar application of different levels of calcium did not show any significant effect and the interaction effect was also non-significant (Table 4.11) (Plate 11).

4.2.10 Head breadth

Genotypes significantly differed for head breadth. The genotype G_1 had the highest mean head breadth (13.40 cm) and the minimum was in the genotype G_4 (9.61 cm) which was on par with G_6 (10.61 cm), G_3 (10.88 cm), G_5 (11.36 cm) and G_2 (11.81 cm).

Different levels of calcium treatments and interaction effect were non-significant. However maximum head breadth (13.90 cm) was recorded in the G_1 C_2 and minimum head breadth (9.60 cm) was in G_4 C_1 and G_4 C_2 respectively (Table 4.12) (Plate 11).

4.2.11 Core length

There was a significant effect among the genotypes for core length. Maximum core length was in the genotype G_2 with (7.88 cm) which was on par with G_1 (7.46 cm) and the minimum core length was G_3 (5.71 cm) (Plate 11).

There was no significant effect among the different levels of calcium application and the minimum core length (6.35 cm) was in control (C_0) treatment. There was no significant interaction effect among different levels of calcium foliar application and cabbage genotypes. The interaction G_3 C_0 and G_3 C_2 had the minimum core length (5.50 cm) and the maximum (8.55 cm) was noticed in the G_2 C_1 (Table 4.13).

Head length

Core length

Head breadth

Plate 11. Observations on head characters of cabbage during off-season

4.2.12 Head index

Head index is the ratio of head length to head breadth of selected heads at marketable stage. There was a significant difference among genotypes for head index. The genotype G_4 recorded the maximum head index (1.31) followed by G_8 (1.19), G_3 and G_6 (1.14) respectively. The minimum head index (0.96) for the genotype G_1, which was on par with G_2 (1.06).

Different levels of calcium treatments had no significant effect on head index. Interaction effect was also non-significant. Head index was maximum (1.37) for G_4 C_0 and lowest (0.92) for G_1 C_2 (Table 4.14).

4.2.13 Harvest index

Harvest index is the ratio of net head weight to gross head weight of selected heads. There was no significant difference among genotypes with regard to harvest index. However the maximum harvest index was for the genotype G_8 (69.60%), and the genotype G_5 recorded least harvest index of 66.80 per cent.

Different levels of calcium treatments and interaction effect were also non-significant. The maximum harvest index (74.61%) was in G_8 C_1 and minimum (62.65%) was recorded from G_2 C_2 (Table 4.15).

4.2.14 Total number of marketable heads per plot

There was no significant effect among the genotypes for total number of marketable heads per plot. However the genotype G_4 recorded the maximum number of (11.00) marketable heads and G_2 registered minimum number of marketable heads (9.00).

Calcium foliar application did not show any significant difference. There was no significant interaction effect between genotypes and different levels of calcium foliar application. However maximum number of marketable heads per plot was in G_6 C_1 and G_4 C_1 (11.50) and it was minimum in interaction G_6 C_2 and G_2 C_1 with (7.00) heads per plot respectively (Table 4.16).

4.2.15 Yield per plot

Significant difference was observed among genotypes for yield per plot. The genotype G_5 recorded maximum yield per plot (6.40 kg) which was on par with G_1 (6.02 kg) and it was minimum (4.65 kg) in the genotype G_8. The genotype G_2 and G_3 were statistically on par. Among different levels of calcium application there was no significant difference.

Interaction effect was also non-significant, the interaction G_5 C_2 showed the maximum yield (6.79 kg) and the lowest yield was recorded by the interaction G_8 C_0 (4.28 kg) (Table 4.17).

4.2.16 Moisture content

There was no significant difference among the genotypes or different levels of calcium application for moisture content. However the genotype G_2 recorded maximum moisture content of (93.13 %) and minimum moisture content was in the genotype G_4 (92.26 %). Interaction effect was also non-significant (Table 4.18).

4.3 PEST AND DISEASE INCIDENCE

4.3.1 Pest incidence

Major pests inside rain shelter were tobacco caterpillar (*Spodoptera litura* F.), head borer (*Helulla undalis*) and flea beetle (*Phyllotreta cruciferae*) during off-season. But there was no significant difference among genotypes for percentage of pest incidence. The maximum pest incidence was in G_2 and G_8 (9.72 %) and the lowest was in the G_4 (5.55 %).

Table 4.11 Effect of cabbage genotypes and different calcium treatments on head length (cm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	12.75	13.05	12.95	**12.91**
G_2	12.85	12.65	12.40	**12.63**
G_3	12.55	12.90	11.60	**12.35**
G_4	13.25	12.15	12.45	**12.61**
G_5	11.85	10.90	11.95	**11.56**
G_6	12.30	12.15	12.15	**12.20**
G_8	11.25	13.00	11.90	**12.05**
Mean (Treatments)	**12.40**	**12.40**	**12.20**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43　　G_2 -Green challenger　　G_3 -Super Ball 50

G_4 -F_1 Border 777　　G_5 -Green voyager　　G_6 -Mahy 118

G_8 -Saint

Table 4.12 Effect of cabbage genotypes and different calcium treatments on head breadth (cm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	12.95	13.35	13.90	**13.40**
G_2	12.05	12.10	11.30	**11.81**
G_3	10.85	11.70	10.10	**10.88**
G_4	9.65	9.60	9.60	**9.61**
G_5	11.05	11.35	11.70	**11.36**
G_6	10.60	10.60	10.65	**10.61**
G_8	9.90	10.65	9.85	**10.13**
Mean (Treatments)	**11.00**	**11.33**	**11.01**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.62			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.13 Effect of cabbage genotypes and different calcium treatments on core length (cm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	7.15	8.15	7.10	**7.46**
G_2	7.20	8.55	7.90	**7.88**
G_3	5.50	6.15	5.50	**5.71**
G_4	5.95	6.15	5.70	**5.93**
G_5	5.85	7.60	7.75	**7.06**
G_6	6.35	5.85	6.35	**6.18**
G_8	6.50	5.80	6.25	**6.18**
Mean (Treatments)	**6.35**	**6.89**	**6.65**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.78			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.14 Effect of cabbage genotypes and different calcium treatments on head index

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	0.99	0.97	0.92	**0.96**
G_2	1.06	1.08	1.05	**1.06**
G_3	1.17	1.11	1.14	**1.14**
G_4	1.37	1.26	1.29	**1.31**
G_5	1.08	0.96	1.01	**1.02**
G_6	1.17	1.13	1.12	**1.14**
G_8	1.13	1.22	1.22	**1.19**
Mean (Treatments)	**1.14**	**1.10**	**1.10**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.08			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43
G_2 -Green challenger
G_3 -Super Ball 50
G_4 -F_1 Border 777
G_5 -Green voyager
G_6 -Mahy 118
G_8 -Saint

Table 4.15 Effect of cabbage genotypes and different calcium treatments on harvest index (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	69.46	67.23	70.58	**69.09**
G_2	67.61	65.60	62.65	**65.28**
G_3	71.61	69.06	66.58	**69.08**
G_4	69.64	66.55	70.99	**69.06**
G_5	68.19	65.99	66.22	**66.80**
G_6	69.81	66.67	68.39	**68.29**
G_8	66.23	74.61	67.95	**69.60**
Mean (Treatments)	**68.93**	**67.95**	**67.62**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.16 Effect of cabbage genotypes and different calcium treatments on total number of marketable heads per plot

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	8.00	11.00	10.00	**9.66**
G_2	10.00	7.00	10.00	**9.00**
G_3	10.50	10.00	8.50	**9.66**
G_4	11.00	11.50	10.50	**11.00**
G_5	9.00	9.50	9.50	**9.33**
G_6	11.00	11.50	7.00	**9.83**
G_8	10.00	7.50	9.50	**9.00**
Mean (Treatments)	**9.92**	**9.71**	**9.28**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Calcium foliar application had no significant on pest incidence. The interaction effect was also non-significant and the maximum incidence was in G_8 C_2 (16.66 %) (Table 4.19) (Plate 12).

4.3.2 Disease incidence

Major diseases were soft rot (*Erwinia carotovora*) and damping-off (*Pythium* sp.). There was no significant effect among genotypes for percentage of disease incidence. Among the seven genotypes, the genotypes G_1 and G_8 recorded the maximum disease incidence (9.71 %) and the minimum incidence was recorded by the genotypes G_5 and G_6 of 4.16 per cent. Different levels of calcium foliar applications did not exhibit any significant difference. Interaction effect was also non-significant. However there was no disease incidence in G_5 C_0, G_6 C_2 and G_2 C_0 respectively. The maximum disease was recorded for G_2 C_2 with 16.66 per cent (Table 4.20) (Plate 12).

4.4 INTERNAL TIPBURN INCIDENCE

There was no significant effect with respect to genotypes for internal tipburn incidence. Different levels of calcium foliar application and interaction effect were also non-significant (Plate 13). Among the seven genotypes, only the genotype G_1 recorded a slight incidence of tipburn (4.16 %) and all others were free from this disorder. Only (C_2) treatment recorded slight incidence of tipburn (1.78 %) (Table 4.21).

4.5 BENEFIT COST RATIO

The total cost of cultivation was recorded Rs. 68.99 per m^2 and total benefit was varied from Rs. 84.60 to Rs. 105.48 per m^2 among the genotypes. The maximum benefit-cost ratio of 1.52 was recorded in the genotype G_5 and it was minimum in the genotype G_8 (1.22). However labour charges accounted 70.15 per cent of the total cost, while the construction and maintenance of structure accounted only 18.11 per cent of the total cost (Table 4.22).

Cabbage slug (*Phylomicus* sp.)

Tobacco caterpillar (*Spodoptera litura*)

Damphing-off (*Pythium* sp.)

Soft rot (*Erwinia carotovora*)

Plate 12. Incidence of pests and diseases during off-season inside rain shelter

Plate 13. Incidence of internal tipburn during off-season inside rain shelter

4.6 SOIL NUTRIENT STATUS

Experiment was laid out in randomized block design with two replications. There were altogether 48 plots (Fig. 1). Three composite soil samples were taken from each experimental plot and analysed for both macro and micronutrients before raising the crop. The results from those plots ear marked for control (C_0) treatments, (C_1) 0.5% calcium foliar spray and (C_2) 1.5% calcium foliar spay are given below.

4.6.1 Initial soil nutrient status

4.6.1.1 Soil pH

There was no significant variation among the earmarked plots with respect to soil pH before raising crop. However the soil pH ranged from 5.30 to 5.85 among the earmarked plots (Table 4.23).

4.6.1.2 Organic carbon

No significant variation was observed among the earmarked plots with respect to organic carbon before raising the crop. The organic carbon content ranged from 1.75 to 1.85 per cent (Table 4.23).

4.6.1.3 Available phosphorus

Experimental plots showed non-significant difference with respect to available P content in the soil before raising the crop. The available P content in the soil ranged from 81.61 to 161.05 kg ha^{-1} (Table 4.23).

4.6.1.4 Available potassium

There was no significant variation among the earmarked plots with respect to available K content in the soil before raising the crop. The available K content in the soil ranged from 249.20 to 285.60 kg ha^{-1} (Table 4.23).

Table 4.17 Effect of cabbage genotypes and different calcium treatments on yield/ plot (kg)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	5.82	5.95	6.30	**6.02**
G_2	5.56	5.41	5.60	**5.52**
G_3	5.37	5.55	4.79	**5.24**
G_4	5.31	4.90	4.70	**4.97**
G_5	6.16	6.25	6.79	**6.40**
G_6	5.20	4.70	4.95	**4.95**
G_8	4.28	5.34	4.33	**4.65**
Mean (Treatments)	**5.39**	**5.44**	**5.35**	
Factors	**C D ($p<0.05$)**			
Factor (G)	0.52			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.18 Effect of cabbage genotypes and different calcium treatments on moisture content (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	92.40	93.10	92.60	**92.70**
G_2	93.00	92.60	93.80	**93.13**
G_3	93.70	92.20	91.60	**92.50**
G_4	92.40	92.80	91.60	**92.26**
G_5	92.80	93.60	91.70	**92.70**
G_6	92.60	93.10	93.40	**93.03**
G_8	93.20	92.80	92.80	92.93
Mean (Treatments)	**92.87**	**92.88**	**92.50**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.19 Effect of cabbage genotypes and different calcium treatments on percentage of plants affected by pests inside rain shelter during off-season

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	8.33	4.16	12.49	**8.33**
G_2	8.33	12.50	8.33	**9.72**
G_3	8.33	0.00	12.50	**6.94**
G_4	0.00	4.16	12.49	**5.55**
G_5	8.33	8.33	4.16	**6.94**
G_6	12.49	0.00	8.33	**6.94**
G_8	0.00	12.49	16.66	**9.72**
Mean (Treatments)	**6.54**	**5.95**	**10.71**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4.20 Effect of cabbage genotypes and different calcium treatments on percentage of plants affected by diseases under rain shelter during off-season

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1	4.16	12.49	12.49	**9.71**
G_2	0.00	4.16	16.66	**6.94**
G_3	4.16	12.50	8.33	**8.33**
G_4	4.16	8.33	4.16	**5.55**
G_5	0.00	4.16	8.33	**4.16**
G_6	4.16	8.33	0.00	**4.16**
G_8	12.49	8.33	8.33	**9.71**
Mean (Treatments)	**6.54**	**5.95**	**10.71**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4. 21 Effect of cabbage genotypes and different calcium treatments on internal tip burn incidence (%) inside rain shelter during off-season

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1	0.00	0.00	12.50	**4.16**
G_2	0.00	0.00	0.00	**0.00**
G_3	0.00	0.00	0.00	**0.00**
G_4	0.00	0.00	0.00	**0.00**
G_5	0.00	0.00	0.00	**0.00**
G_6	0.00	0.00	0.00	**0.00**
G_8	0.00	0.00	0.00	**0.00**
Mean (Treatments)	**0.00**	**0.00**	**1.78**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

Table 4. 22 Economics of cultivation of cabbage genotypes during off-season inside rain shelter

Genotypes	price of cabbage/ kg (Rs.)	Total cost/ m^2 (Rs.)	Yield/ m^2 (kg)	Total benefit/ m^2 (Rs.)	Benefit cost ratio
G_1	36.00	68.99	2.80	100.8	1.46
G_2	36.00	68.99	2.64	95.04	1.37
G_3	36.00	68.99	2.54	91.44	1.32
G_4	36.00	68.99	2.45	88.20	1.27
G_5	36.00	68.99	2.93	105.48	1.52
G_6	36.00	68.99	2.45	88.20	1.27
G_8	36.00	68.99	2.35	84.60	1.22

G_1 - NS 43 G_2 -Green challenger G_3 -Super Ball 50

G_4 -F_1 Border 777 G_5 -Green voyager G_6 -Mahy 118

G_8 -Saint

4.6.1.5 Available calcium

No significant difference was observed among the earmarked plots with respect to available Ca content in the soil before raising the crop. The available Ca content in the soil ranged from 816.25 to 954.12 mg kg^{-1} (Table 4.24).

4.6.1.6 Available magnesium

There was no significant variation among the earmarked plots with respect to available Mg content in the soil before raising the crop. The available Mg content in the soil ranged from 169.50 to 239.25 mg kg^{-1} (Table 4.24).

4.6.1.7 Available iron

Earmarked plots showed non-significant difference with respect to available Fe content in the soil before raising the crop. The available Fe content in the soil ranged from 29.96 to 31.77 mg kg^{-1} (Table 4.24).

4.6.1.8 Available manganese

There was no significant variation among the earmarked plots for available Mn content in the soil before raising the crop. The available Mn content in the soil ranged from 46.13 to 51.33 mg kg^{-1} (Table 4.24).

4.6.2 Final soil nutrient status

4.6.2.1 Soil pH

There was no significant variation with respect to genotypes for soil pH after the crop harvest. The plots with genotypes G_1 and G_5 recorded the pH value of 5.23 and 5.29 respectively. Different levels of calcium foliar application had a significant effect on soil pH. The mean value of treatment (C_2) recorded maximum pH (6.07) and values of other treatments were on par. There was significant interaction among the genotypes and different levels of calcium foliar application with respect to soil pH. The maximum soil pH (6.90) was recorded in

Table 4.23 (a) Initial soil nutrient status

Treatments	**Soil pH**	**Organic carbon (%)**	**Available phosphorus (kg ha^{-1})**	**Available potassium (kg ha^{-1})**
C_0 (0%)	5.60	1.85	91.88	285.60
C_1 (0.5%)	5.85	1.75	81.61	249.20
C_2 (1.5%)	5.30	1.84	161.05	282.24
C.D. ($p<0.05$)	**NS**	**NS**	**NS**	**NS**

Table 4.24 (b) Initial soil nutrient status

Treatments	**Available calcium (mg kg^{-1})**	**Available magnesium (mg kg^{-1})**	**Available iron (mg kg^{-1})**	**Available manganese (mg kg^{-1})**
C_0 (0%)	816.25	169.50	31.77	51.02
C_1 (0.5%)	954.12	239.25	29.96	51.33
C_2 (1.5%)	938.00	236.75	31.20	46.13
C.D. ($p<0.05$)	**NS**	**NS**	**NS**	**NS**

the interaction $G_1 C_2$ followed by $G_5 C_0$, $G_5 C_2$ and $G_5 C_1$ respectively. The lowest soil pH was recorded in the interaction $G_1 C_0$ (4.29) (Table 4.25).

4.6.2.2 Organic carbon

There was a significant difference between treatments with respect to genotypes for organic carbon status in soil after the crop harvest. The plots with genotype G_5 recorded the maximum organic carbon (1.93 %) followed by G_1 with 1.59 per cent organic carbon content. There was no significant difference with different levels of calcium application. The maximum organic carbon content was in C_0 (1.86 %). Interaction effect was also non-significant. The interaction $G_5 C_2$ recorded the highest organic carbon with 1.98per cent and lowest was in $G_1 C_2$ (1.42 %) (Table 4.26).

4.6.2.3 Available phosphorus

No significant variation was observed between treatments with different genotypes. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available P content in soil after the crop harvest (Table 4.27).

4.6.2.4 Available potassium

Genotypes exhibited non-significant variation between treatments and different levels of foliar sprays of Ca with respect to available K content in soil after the crop harvest. There was a significant interaction effect with respect to available K among genotypes and different levels of Ca foliar sprays in terms of available K. The interaction $G_1 C_1$ had highest available K with 492.80 kg ha^{-1}, followed by $G_5 C_1$, $G_1 C_1$, $G_5 C_0$ and $G_5 C_2$ interaction. The available K was least in $G_1 C_2$ interaction with 203.84 kg ha^{-1} (Table 4.28).

Table 4. 25 Interaction effect of different calcium treatments and cabbage genotypes on soil pH

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	4.29	4.51	6.90	**5.23**
G_5 (Green Voyager)	5.41	5.22	5.25	**5.29**
Mean (Treatments)	**4.85**	**4.87**	**6.07**	
Factors	**C.D. ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	0.83			
Factor (G X C)	1.17			

Table 4. 26 Interaction effect of different calcium treatments and cabbage genotypes on organic carbon (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	1.78	1.58	1.42	**1.59**
G_5 (Green Voyager)	1.95	1.88	1.98	**1.93**
Mean (Treatments)	**1.86**	**1.73**	**1.70**	
Factors	**C.D. ($p<0.05$)**			
Factor (G)	0.18			
Factor (C)	NS			
Factor (G X C)	NS			

4.6.2.5 Available calcium

No significant variation was observed between treatments with different genotypes. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Ca content in soil after the crop harvest (Table 4.29).

4.6.2.6 Available magnesium

There was no significant variation between treatments with different genotypes. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Mg content in soil after the crop harvest (Table 4.30).

4.6.2.7 Available iron

Genotypes exhibited non-significant variation between treatments and different levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Fe content in soil after the crop harvest (Table 4.31).

4.6.2.8 Available manganese

There was no significant variation between treatments with different genotypes. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Mn content in soil after the crop harvest (Table 4.32).

4.6.3 Nutrient content in leaf and head at harvest

4.6.3.1 Nitrogen content in leaf

There was no significant variation among the different genotypes and levels of foliar spray of Ca. Interaction effect also did not give any significant difference in terms of nitrogen content in leaf (Table 4.33).

Table 4.27 Interaction effect of different calcium treatments and cabbage genotypes on available phosphorous (kg ha^{-1})

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	208.68	165.64	144.52	**172.94**
G_5 (Green Voyager)	217.89	118.28	108.55	**148.24**
Mean (Treatments)	**213.28**	**141.96**	**126.53**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.28 Interaction effect of different calcium treatments and cabbage genotypes on available potassium (kg ha^{-1})

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	492.80	245.84	203.84	**314.16**
G_5 (Green Voyager)	231.84	283.36	230.72	**248.64**
Mean (Treatments)	**362.32**	**264.60**	**217.28**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	179.44			

Table 4.29 Interaction effect of different calcium treatments and cabbage genotypes on available calcium (mg kg^{-1})

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	573.75	550.75	634.25	**586.25**
G_5 (Green Voyager)	614.62	648.50	702.25	**655.12**
Mean (Treatments)	**594.18**	**599.62**	**668.25**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.30 Interaction effect of different calcium treatments and cabbage genotypes on available magnesium (mg kg^{-1})

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	11.42	10.68	12.13	**11.41**
G_5 (Green Voyager)	9.78	12.51	14.21	**12.16**
Mean (Treatments)	**10.60**	**11.59**	**13.17**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

4.6.3.2 Nitrogen content in head

Genotypes showed no significant variation between treatments and levels of foliar spray of Ca. Interaction effect also did not give any significant difference in terms of nitrogen content in head (Table 4.34).

4.6.3.3 Potassium content in leaf

No significant variation was observed between treatments with different genotypes. Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of potassium content in leaf (Table 4.35).

4.6.3.4 Potassium content in head

Genotypes exhibited non-significant variation between treatments. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of potassium content in head (Table 4.36).

4.6.3.5 Phosphorus content in leaf

Genotypes exhibited non-significant variation with respect to phosphorus content in leaf. Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of phosphorus content in leaf (Table 4.37).

4.6.3.6 Phosphorus content in head

No significant variation was observed with regard to phosphorus content in head among genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of phosphorus content in head (Table 4.38).

4.6.3.7 Calcium content in leaf

There was no significant difference between treatments with different genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of calcium content in leaf (Table 4.39).

Table 4.31 Interaction effect of different calcium treatments and cabbage genotypes on available iron (mg kg^{-1})

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	16.93	13.38	13.29	**14.53**
G_5 (Green Voyager)	15.85	17.13	11.78	**14.92**
Mean (Treatments)	**16.39**	**15.25**	**12.53**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.32 Interaction effect of different calcium treatments and cabbage genotypes on available manganese (mg kg^{-1})

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	43.14	42.75	38.46	**41.45**
G_5 (Green Voyager)	42.96	41.60	39.44	**41.33**
Mean (Treatments)	**43.05**	**42.17**	**38.95**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.33 Interaction effect of different calcium treatments and cabbage genotypes on nitrogen content in leaf (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	2.94	2.78	2.83	**2.85**
G_5 (Green Voyager)	3.02	3.25	2.74	**3.00**
Mean (Treatments)	**2.98**	**3.01**	**2.78**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.34 Interaction effect of different calcium treatments and cabbage genotypes on nitrogen content in head (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	3.34	2.64	2.97	**2.98**
G_5 (Green Voyager)	2.62	2.95	2.56	**2.71**
Mean (Treatments)	**2.98**	**2.79**	**2.76**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

4.6.3.8 Calcium content in head

Genotypes exhibited non-significant variation with respect to calcium content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of calcium content in head (Table 4.40).

4.6.3.9 Magnesium content in leaf

No significant difference was observed with regard to magnesium content in leaf among genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of magnesium content in leaf (Table 4.41).

4.6.3.10 Magnesium content in head

Genotypes exhibited non-significant variation with regard to magnesium content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of magnesium content in head (Table 4.42).

4.6.3.11 Iron content in leaf

Genotypes exhibited non-significant variation with respect to iron content in leaf. Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of iron content in leaf (Table 4. 43).

4.6.3.12 Iron content in head

There was no significant difference with regard to iron content in head among the genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of iron content in head (Table 4. 44).

Table 4.35 Interaction effect of different calcium treatments and cabbage genotypes on leaf potassium (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	1.26	1.31	1.35	**1.31**
G_5 (Green Voyager)	1.08	1.45	1.28	**1.27**
Mean (Treatments)	**1.17**	**1.38**	**1.32**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.36 Interaction effect of different calcium treatments and cabbage genotypes on head potassium (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	0.96	0.94	1.04	**0.98**
G_5 (Green Voyager)	1.03	1.04	0.97	**1.01**
Mean (Treatments)	**1.00**	**0.99**	**1.00**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.37 Interaction effect of different calcium treatments and cabbage genotypes on leaf phosphorous (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	0.20	0.21	0.22	**0.21**
G_5 (Green Voyager)	0.16	0.20	0.22	**0.19**
Mean (Treatments)	**0.18**	**0.20**	**0.22**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.38 Interaction effect of different calcium treatments and cabbage genotypes on head phosphorous (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	0.28	0.22	0.32	**0.27**
G_5 (Green Voyager)	0.31	0.33	0.25	**0.30**
Mean (Treatments)	**0.29**	**0.27**	**0.28**	
Factors	**C D (p<0.05)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.39 Interaction effect of different calcium treatments and cabbage genotypes on leaf calcium (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	1.12	1.17	1.17	**1.15**
G_5 (Green Voyager)	0.96	0.99	1.20	**1.05**
Mean (Treatments)	**1.04**	**1.08**	**1.18**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.40 Interaction effect of different calcium treatments and cabbage genotypes on head calcium (%)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	0.17	0.16	0.16	**0.16**
G_5 (Green Voyager)	0.17	0.16	0.17	**0.16**
Mean (Treatments)	**0.17**	**0.16**	**0.16**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.41 Interaction effect of different calcium treatments and cabbage genotypes on leaf magnesium (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	0.41	0.50	0.40	**0.43**
G_5 (Green Voyager)	0.31	0.39	0.51	**0.40**
Mean (Treatments)	**0.36**	**0.45**	**0.45**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.42 Interaction effect of different calcium treatments and cabbage genotypes on head magnesium (%)

Genotypes	**C_0 (0%)**	**C_1 (0.5%)**	**C_2 (1.5%)**	**Mean (Genotypes)**
G_1 (NS 43)	0.25	0.31	0.40	**0.32**
G_5 (Green Voyager)	0.38	0.27	0.24	**0.30**
Mean (Treatments)	**0.31**	**0.29**	**0.32**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

4.6.3.13 Manganese content in leaf

There was a significant variation among the genotypes with respect to manganese content in leaf. The mean value of genotype G_1 recorded maximum manganese content in leaf (57.71 ppm) followed by G_5 with 44.43 ppm. There was significant difference with different levels of foliar sprays of Ca. The treatment (C_1) had higher (55.97 ppm) manganese content in leaf followed by treatments C_0 and C_2. There was interaction effect with respect to genotypes and different levels of calcium foliar application. There was a significant difference among genotypes and Ca foliar sprays with respect to manganese content in leaf. The interaction G_1 C_1 recorded higher manganese content in leaf with 69.80 ppm followed by interaction G_1 C_2, G_5 C_2, G_1 C_0 and G_5 C_1. The manganese content in leaf was lesser in G_5 C_0 interaction with 39.10 ppm (Table 4.45).

4.6.3.14 Manganese content in head

There was a significant difference among the genotypes for manganese content in head. The genotype G_1 recorded higher manganese content (49.53 ppm) in head followed by G_5 with 36.26 ppm. Different levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of manganese content in head (Table 4.46).

Table 4.43 Interaction effect of different calcium treatments and cabbage genotypes on leaf iron (ppm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	299.85	275.30	286.20	**287.11**
G_5 (Green Voyager)	276.70	280.35	278.55	**278.53**
Mean (Treatments)	**288.27**	**277.82**	**282.37**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.44 Interaction effect of different calcium treatments and cabbage genotypes on head iron (ppm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	234.10	246.70	250.75	**243.85**
G_5 (Green Voyager)	235.00	238.60	222.90	**232.16**
Mean (Treatments)	**234.55**	**242.65**	**236.82**	
Factors	**C D ($p<0.05$)**			
Factor (G)	NS			
Factor (C)	NS			
Factor (G X C)	NS			

Table 4.45 Interaction effect of different calcium treatments and cabbage genotypes on leaf manganese (ppm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G_1 (NS 43)	48.95	69.80	54.40	**57.71**
G_5 (Green Voyager)	39.10	42.15	52.05	**44.43**
Mean (Treatments)	**44.02**	**55.97**	**53.22**	
Factors	**C D (p<0.05)**			
Factor (G)	0.01			
Factor (C)	0.01			
Factor (G X C)	0.02			

Table 4.46 Interaction effect of different calcium treatments and cabbage genotypes on head manganese (ppm)

Genotypes	C_0 (0%)	C_1 (0.5%)	C_2 (1.5%)	Mean (Genotypes)
G1 (NS 43)	49.20	50.20	49.20	**49.53**
G5 (Green voyager)	39.80	34.85	34.15	**36.26**
Mean (Treatments)	**44.50**	**42.52**	**41.67**	
Factors	**C D (p<0.05)**			
Factor (G)	0.01			
Factor (C)	NS			
Factor (G X C)	NS			

DISCUSSION

5. DISCUSSION

Cabbage (*Brassica oleracea* L. var. *capitata*) is an important vegetable in almost all parts of the world. It is an important winter vegetable grown during winter season in northern parts of India mainly for its leafy heads. Recently cabbage cultivation has gained popularity in the plains of Kerala also. But cabbage cultivation during off-season (rainy season) is not possible in open field due to heavy mansoon rains which results in poor or no head formation (Malu,2011). High plant mortality in the field conditions makes the cabbage cultivation unprofitable to farmers even though the sale price of cabbage heads is high. To overcome this problem, off-season cultivation of cabbage inside a low cost naturally ventilated poly house or rain shelter was found ideal.

Cabbage plants grown in greenhouses or rain shelters are severely affected by tipburn than field grown plants (Kurien, 2014). Cox and Dearman (1976) revealed that under protected conditions higher growth rate is associated with restricted calcium supply from soil leading to increased risk of internal tipburn. Tipburn is a calcium related physiological disorder which cause reduction in nutritional quality, yield and finally poor returns to farmers. The present study entitled "Evaluation of cabbage (*Brassica oleracea* var. *capitata*) genotypes for head compactness and internal tipburn resistance under rain shelter" was undertaken to identify the ideal genotypes for tipburn resistance and to find out the effect of Ca foliar application for off-season cabbage production inside rain shelter.

The results of the study are discussed under the following headlines.

5.1. Influence of genotypes and Ca foliar application on qualitative characters

5.2. Influence of genotypes and Ca foliar application on quantitative characters

5.3. Influence of genotypes and Ca foliar application on pest and disease incidence

5.4. Influence of genotypes and Ca foliar application on internal tipburn incidence

5.5. Benefit cost ratio

5.6. Soil nutrient status

5.1. INFLUENCE OF GENOTYPES AND CALCIUM FOLIAR APPLICATION ON QUALITATIVE CHARACTERS

5.1.1 Head compactness

Singh *et al.* (2010) reported that the transportability, marketability and shelf-life of cabbage heads is dependent on the head compactness. Cabbage genotypes raised under rain shelter showed variation with respect to head compactness. Only the genotype G_1 (NS 43) formed loose heads in C_2 (1.5 %) treatment and medium compact heads in C_0 (control) and C_1 (0.5 %) treatments. All other genotypes produced compact heads irrespective of Ca application. Kurien (2014) also reported that the heads of NS 43 were loose in all planting dates. Singh *et al.* (2010a) reported that head compactness is negatively correlated with net head weight and plant spread. There are also reports that genotypes may vary in their head compactness (Moniruzzaman, 2011). Malu (2011) also reported that head compactness vary with genotypes. The hybrid NS 43 formed compact heads while NS 183 formed medium compact to compact heads inside rain shelter during off-season.

In the interaction G_1C_2 only head was loose. The net head weight was more for this treatment. There was slight incidence of tipburn which shows Ca deficiency. According to Marschner (1995) Ca deficiency affects cell wall development and this might have lead to loose head formation in this combination.

5.1.2 Head shape

In cabbage head shape is usually expressed in terms of polar and equatorial diameter and these ratios are 0.8 to 1.0 for spherical heads, 0.6 or less for drum head and more than 1.0 for conical head (Ram, 1997). There will be variation in head shape with respect to genotypes (Malu, 2011). Posta and Berar (2007) reported that all the seven cabbage hybrids produced globular shape head having the polar: equatorial diameter ratio (0.6) and for round shape heads (1.0). Round shape cultivar have preference over semi round cultivar due to its attractiveness (Bhatt *et al.,* 2008a). In the present investigation, there was variation with respect to head shape among cabbage genotypes raised inside rain shelter. Only genotype G_1 (NS 43) produced round heads and all other genotypes (G_2, G_3, G_4, G_5, G_6 and G_7) produced conical heads irrespective of the treatments. Our findings were similar to the reports of (Kurien, 2014) who reported that during all the planting dates NS 43 produced round shaped heads.

Temperature as significant effect on cabbage head shape (Sundstrom and Story, 1984). Head shape is a result of cumulative environmental conditions and the conditions that prevails earlier on the plant and crop development may have stronger influence on the same (Kleinhenz and Wszelaki, 2003). Philips and Rix (1993) opined that most of the consumer's prefer the round headed cabbages in the market as compared to conical and pointed heads.

5.2 INFLUENCE OF GENOTYPES AND CALCIUM FOLIAR APPLICATION ON QUANTITATIVE CHARACTERS

5.2.1 Plant spread

Plant spread is the average distance between two outer leaves of a cabbage plant. In cabbage smaller plant spread is preferred as it allows greater plant population per unit area (Chaubey *et al.,* 2006). Plant spread has significant positive correlation with gross plant weight, head length, head breadth and core length (Singh *et al.,* 2010).

In the present investigation, there was no significant difference with respect to plant spread among genotypes. However the minimum plant spread (45.10 cm) was recorded the genotype G_8 (Saint) and it was maximum in G_1 (NS 43) with 50.70cm. There was no significant effect with calcium application and the maximum plant spread was in the treatment C_2 with (47.50 cm) and other treatments were on par. According to Suseela (2002) the maximum plant spread in cauliflower was associated with increased yield per plant. Here also more plant spread was recorded by genotype G_1 (NS 43) which recorded higher yield. Malu (2011) also reported the hybrid NS 43 recorded the maximum plant spread (48.20 cm) inside rain shelter (Fig 5.1). The minimum plant spread (56.93 cm) was recorded in June 30th planting and it was maximum (59.90 cm) in May 30th planting for NS 43 (Kurien, 2014). A study conducted at ARS Mannuthy, revealed that among thirty cabbage hybrids, the maximum plant spread (78 cm) was achieved by NS 43 during on-season (KAU, 2016). The increase in plant height or plant spread in cauliflower recorded by the application of ½ NPK + FYM 10 t ha^{-1} + VAM might be due to the more availability of nitrogenous compounds to the plants from organic manures which increased the foliage and thereby increased the photosynthesis rate resulting in increased plant height or plant spread. It was due to the cell elongation by the presence of nitrogenous compounds as reported by Chaurasia *et al.* (2008).

The different Ca treatments exhibited non-significant difference with respect to plant spread. The genotypes and different levels of calcium foliar application did not show any interaction effect and minimal plant spread was recorded in G_8 C_2 (44.60 cm) and it was maximum in G_1 C_0 (52.10 cm).

5.2.2 Number of non-wrapping leaves

Non-wrapping leaves are the leaves formed at the basal part of the plant. They will not cover the head portion. Lesser number of non-wrapping leaves is a desirable character in cabbage (Sharma *et al.*, 2006). In the current study, there was significant difference among cabbage genotypes for number of non-wrapping leaves. Genotype G_4 (F_1 Border 777) recorded maximum number of non-wrapping leaves of 9.26 followed by G_1, G_2, G_5 respectively and it was least in the genotype G_8 (Saint) with 7.70.

Agarwal *et al.* (1972) reported that the increased number of non-wrapping leaves on the cabbage heads is an unacceptable horticultural trait. The hybrid NS

43 had the lowest number of non-wrapping leaves (9.0) inside rain shelter and which was on par with NS 183 (9.08). In open field hybrid NS 43 produced the lowest non-wrapping leaves (9.33) and it was highest in NS 183 (16.08) during on-season (Malu, 2011). There was no significant difference for number of wrapping leaves and planting dates. The maximum number of wrapping leaves (8.35) was recorded for June 15th planting and it was minimum (7.15) for May 30th planting (Kurien, 2014). In a study conducted at ARS Mannuthy, it was reported that among thirty cabbage hybrids. The hybrid NS 43 was recorded the maximum number of non-wrapping leaves (KAU, 2016).

The treatments didn't show any significant difference with calcium foliar application. The maximum number of non-wrapping leaves was noticed in the control (C_0) treatment (8.75) and it was lowest (8.37) in C_2 treatment. There was no significant interaction among the genotypes for different calcium treatments. The maximum number of 9.60 non-wrapping leaves was registered in G_4 C_1 and it was minimum (7.10) in G_8 C_0.

5.2.3 Number of wrapping leaves

Wrapping leaves are the leaves that cover the head portion of cabbage. There was significant difference among genotypes with regard to number of wrapping leaves. The maximum number of wrapping leaves (14.23) was recorded in the genotype G_6 (Mahy 118) followed by G_3, G_8, G_5, G_2 and G_4 respectively and it was lowest (8.60) in G_1 (NS 43) which recorded the maximum yield (Fig 5.2). The lower number of wrapping leaves was preferred.

Genotypes also differ with respect to number of wrapping leaves. Malu (2011) opined that during off-season, the number of wrapping leaves was lower in all the cabbage hybrids grown inside rain shelter. The highest number of wrapping leaves (28.97) and (30.95) was recorded in K-S Cross which was on par with Green-621 and Green Rich. The lowest number of wrapping leaves (22.13) was produced by Green Coronet (Moniruzzaman, 2011). The minimum number of wrapping leaves (3.9) was recorded in May 30th planting and it was maximum

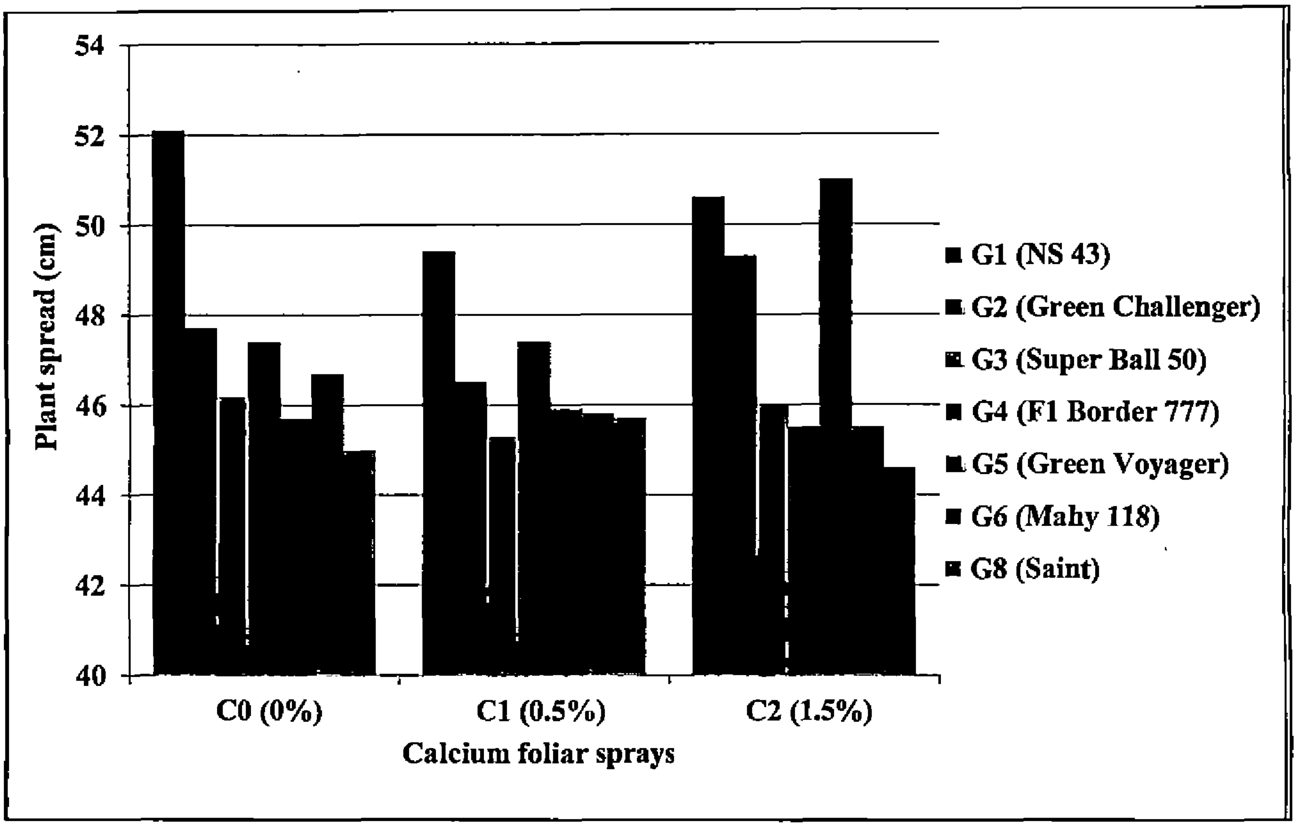

Fig 5.1 Effect of calcium foliar application on plant spread

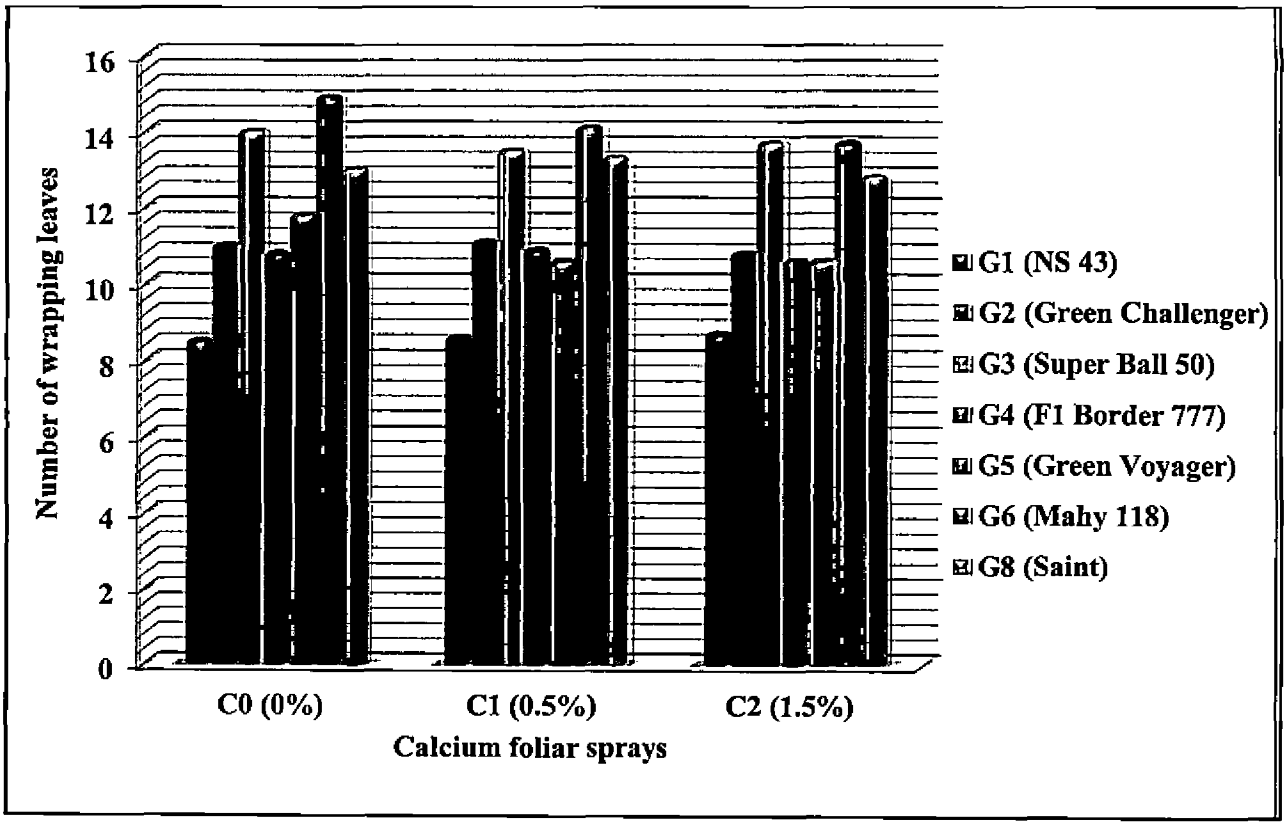

Fig 5.2 Effect of calcium foliar application on number of wrapping leaves

(6.15) for June 30th planting (Kurien, 2014). At ARS Mannuthy, among the thirty cabbage hybrids, the hybrid Disha recorded the maximum number of wrapping leaves (KAU, 2016).

Different calcium foliar application treatments showed non-significant effect, the maximum number of wrapping leaves was recorded in control (C_0) treatment and the other treatments were on par. The interaction effect was also non-significant with respect to different calcium foliar application. The interaction G_1 C_0 recorded the lowest and highest number of wrapping leaves (8.50) and (14.90) respectively. This shows that Ca has not much significance on number of wrapping leaves.

5.2.4 Stalk length

Stalk length is the distance from ground level to the first non-wrapping leaves. Shorter stalk length is one of the desirable and most acceptable horticultural traits for cabbage (Sharma *et al.,* 2006). In the present study, there was significant difference among the genotypes with regard to stalk length. The minimum stalk length was recorded in genotypes G_4 (F_1 Border 777) and G_5 (Green Voyager) with (5.58 cm) and (5.68 cm) respectively and it was maximum in G_6 (Mahy 118) (7.63 cm). Our findings are also similar with the results observed by Malu (2011) who also reported that hybrid NS 35 recorded the maximum stalk length (11.99 cm) and it was lowest (6.99 cm) in NS 43 during off-season inside rain shelter. During on-season, minimum stalk length was achieved by same hybrid and it was maximum for Disha (9.15 cm) in rain shelter. Early planting induces lesser stalk length than late planting of cabbage as reported by Pradeepkumar and George (2009). Kurien (2014) observed significant difference with regard to stalk length on different planting dates inside rain shelter during off-season. The least stalk length (2.64 cm) was noticed for June 30th planting and it was highest (3.45 cm) in the May 30th planting for NS 43.

There was no significant difference with different calcium treatments on stalk length. The maximum stalk length (6.86 cm) was recorded in (C_1) treatment and it was lowest (6.47 cm) for treatment (C_2). There was significant interaction among the genotypes and different levels of calcium treatments. The maximum stalk length (8.20 cm) was recorded in the interaction G_6 C_0 which was on par with G_3 C_0, G_2 C_1, G_3 C_2 and it was lowest (5.25 cm) in G_4 C_0 and G_5 C_0 (5.35 cm) respectively. This shows that Ca foliar application might have increased the stalk length.

5.2.5 Days to 50% head formation

The number of days from transplanting to the date when 50% of the plants attain head formation is considered as the days to 50% head formation. Different growing conditions showed a significant difference on cauliflower for number of days to curd formation. The curd formation was early in the greenhouse and it was late in open field (Suseela, 2002). Higher morning relative humidity and elevated temperature were positively correlated with days to 50% head formation and low temperature and relative humidity in the noon were negatively correlated with days to 50% head formation during off-season as reported by Malu (2011). In the current study, there was a significant difference among genotypes for days to 50 % head formation. However the genotype G_1 (NS 43) was early (59.50) to achieve 50% head formation and the genotype G_8 (Saint) took maximum number (65.70) of days to 50% head formation (Fig 5.3). Kurien (2014) reported that there was a significant difference with respect to days to 50% head formation at different planting dates. Early head formation (47.9) was noticed for May 30th planting and it was late (59.00) in the July 15th planting inside rain shelter during off-season. The early curd initiation in cauliflower may be due to the stimulation effect of organics and VAM or presence of phosphorus on growth hormones (Chaurasia *et al.*, 2008).

There was no significant effect with different levels of calcium foliar application. The treatment mean for days to 50% head formation were on par. The interaction G_1 C_0 was early to form heads (59.50) and the interaction G_8 C_1 was late (66.90) to 50% head formation. However the Ca foliar treatments had no significant effect on earliness and the control treatment was early for 50% head formation.

5.2.6 Days to 50% head maturity

The number of days from transplanting to date when at least 50% of plants produced marketable heads was recorded. Attainment of maximum size is considered as an index of cabbage maturity (Isenberg *et al.,* 1975). In the present investigation also, there was a significant difference among the genotypes for days to 50% head maturity. However genotype G_1 (NS 43) was early (75.96) to 50% head maturity and it was late for G_4 (F_1 Border 777) which took maximum number (104.20) of days to 50% head maturity inside rain shelter during off-season (Fig 5.4).The observations go in line with the findings of Malu (2011). She reported that there was significant difference among the genotypes with respect to 50% head maturity. The hybrid NS 43 recorded 50% head maturity 74.50 days after transplanting inside rain shelter during off-season. The early curd maturity in cauliflower may be due to the stimulation effect of organics and VAM or presence of phosphorus on growth hormones and also increased rate of nitrogen application might have delayed curd maturity (Chaurasia *et al.,* 2008).

In the present study early maturing genotype G_1 (NS 43) produced maximum yield as compared to late maturing genotype G_4 (F_1 Border 777) which produced lower yield. Chaubey *et al.* (2006) reported that late maturity of cabbage during winter planting is due to lower temperature resulting in delayed vegetative growth and head formation as compared to spring summer planting. An experiment conducted at ARS Mannuthy, revealed that the cabbage hybrids namely Gayathri and Super Gayathri were early to head maturity in 93 and 95 days respectively during on-season (KAU, 2016).

There was no significant difference with respect to different calcium foliar application. The treatment C_2 (1.5 %) recorded 90.42 days to 50% head maturity and other treatments were on par. Among the interaction G_1 C_2 was early to 50% head maturity (73.80) and it was late in G_4 C_0 which took 107.50 days to 50%

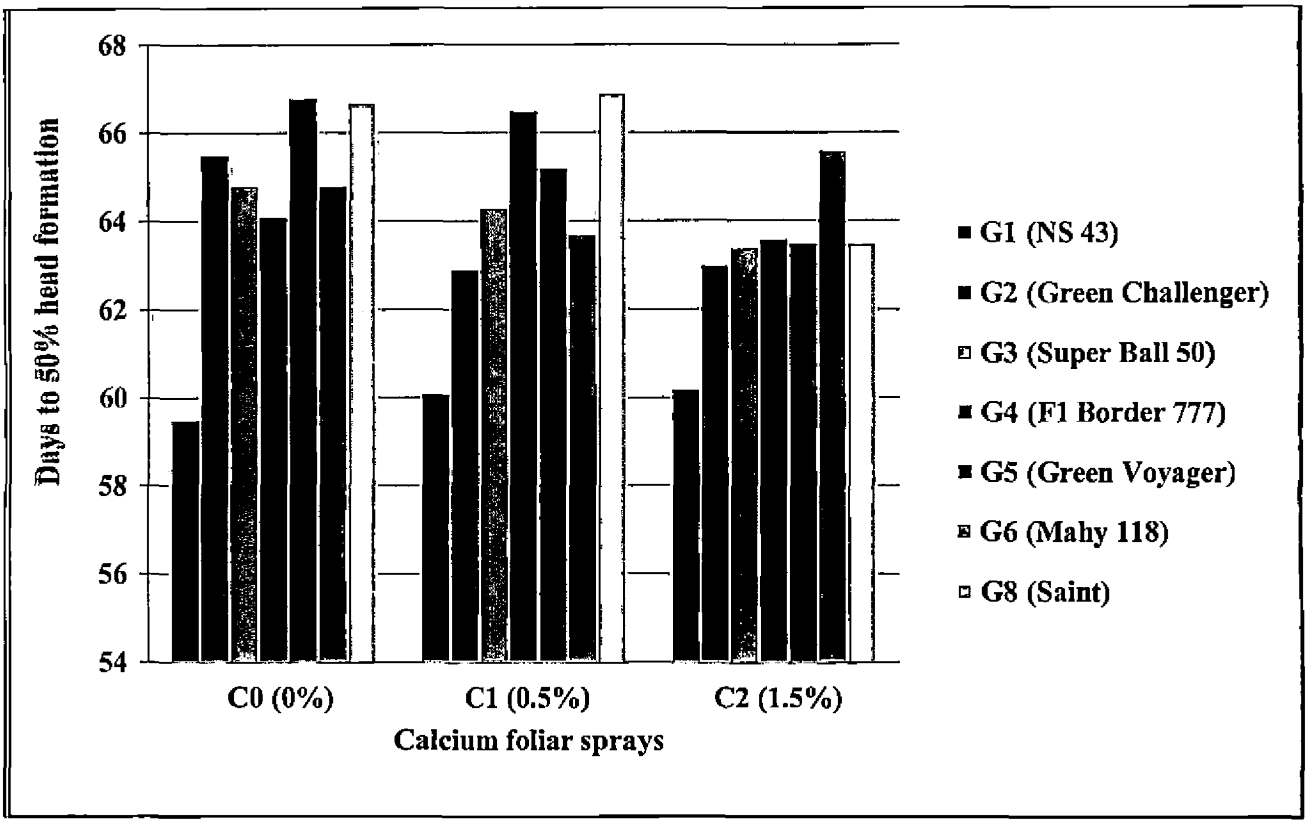

Fig 5.3 Effect of calcium foliar application on days to 50% head formation

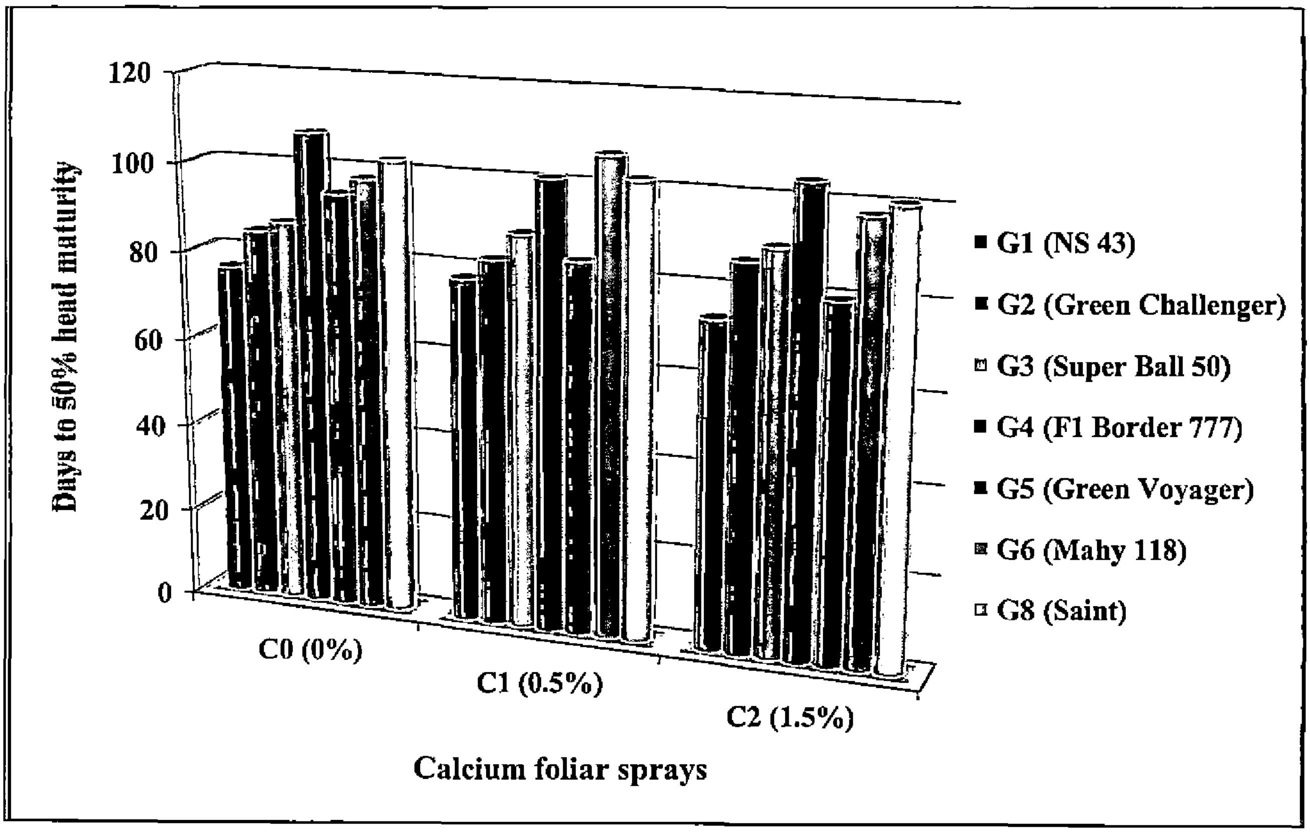

Fig 5.4 Effect of calcium foliar application on days to 50% head maturity

head maturity. Though it was non-significant, there was a variation with respect to head maturity. However Ca foliar application (1.5 %) reduced the maturity period over the control.

5.2.7 Gross head weight

Gross head weight is the weight of head along with non-wrapping leaves and stalk which was recorded at marketable stage. There is a variation with respect to genotypes for gross head weight. In the present study, there was a significant difference with respect to genotypes for gross head weight. The maximum gross head weight was recorded in G_1 (NS 43) with (1136.66 g) and it was lowest for the genotype G_8 (Saint) (901.50 g) (Fig 5.5). Pradeepkumar and George (2009) revealed that early planting of cauliflower resulted in higher gross head weight, net head weight and total yield. Moniruzzaman (2011) reported that hybrid Green Coronet produced the highest gross head weight (2.77 kg) and it was lowest (2.07 kg) in Green-621. Natasa (2012) reported that early planting of cabbage resulted in bigger heads while late planting resulted in smaller heads, which might be the influence of growing season. Malu (2011) revealed that the late maturing hybrid NS 35 recorded the maximum gross head weight (2401.00 g) and similar results were reported by Damato *et al.* (1996) who also reported that late maturing genotypes consistently gave higher gross head weight. But in contrary to that G_1 was early in the present study which had maximum (1136.66 g) gross head weight.

The calcium foliar application had no significant difference and the maximum gross head weight was in the treatment (C_1) with 989.85g and the control treatment (C_0) recorded the lowest gross head weight (926.00 g). There was a significant interaction among different levels of Ca application. The maximum gross head weight (1365 g) was achieved in G_1 C_2 and the lowest gross head weight (790 g) in the interaction G_4 C_1. These results shown that gross head weight increases with Ca foliar application, but it varies with genotypes.

5.2.8 Net head weight

The weight of individual heads in observed as the net head weight. In the present study, there was a significant difference with regard to net head weight among the genotypes. The maximum net head weight (787.33 g) was achieved in G_1 (NS 43) and the minimum net head weight (630.33 g) for G_6 (Mahy 118) (Fig 5.6). Our findings were similar with Malu (2011) who reported that the hybrid NS 43 recorded a net head weight (553.5 g) during off-season inside rain shelter and the same hybrid recorded the maximum net head weight (945.5 g) during on-season. The minimum net head weight (486.25 g) was recorded in June 15th planting which was due to unfavourable growing conditions during head formation stage as reported by Elavarasan (2011). A study conducted by Kurien (2014) reported that the maximum net head weight (818.75 g) was positively correlated with gross head weight (1345 g) in NS 43 of cabbage grown inside rain shelter during off-season. In this study also the maximum net head weight and gross head weight was for NS 43 and the cabbage hybrid Kalyani recorded the maximum net head weight of 1.76 kg at ARS, Mannuthy (KAU, 2016). Nandi and Nayak (2008) reported that the highest head weight (1.5 kg) was recorded by 3 foliar sprays of 100 ppm of zinc (as zinc sulphate) followed by100 ppm boron (as borax), 100 ppm manganese (as manganese sulphate), 100 ppm copper (as copper sulphate), 100 ppm molybdenum (as ammonium molybdate), 100 ppm iron (as iron sulphate) and the cabbage hybrid Hari Rani Gol. The favourable effects of zinc can be attributed that the element is essential in nitrogen metabolism and it also increases the synthesis of auxin which promotes the cell size and also the effect of boron in improving head weight could be due to its involvement in cell division and cell expansion. This might have increased head weight (Pal *et al.*, 2004). The maximum curd weight was achieved by application of ½ NPK + Pressmud 5 t ha $^{-1}$ + VAM. The increased curd weight was due to high rate of photosynthesis form larger leaf area and translocation of photosynthates towards the curd (Chaurasia *et al.*, 2008).

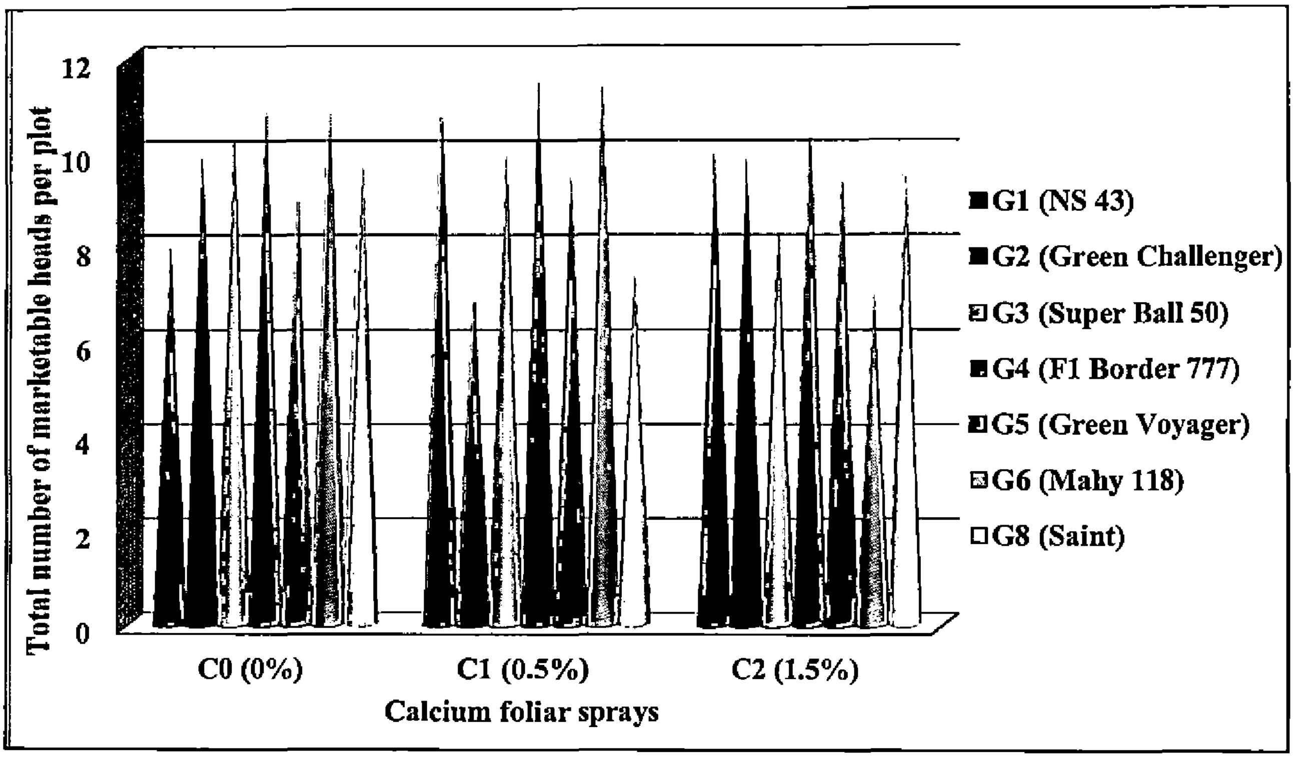

Fig 5.7 Effect of calcium foliar application on total number of marketable heads per plot

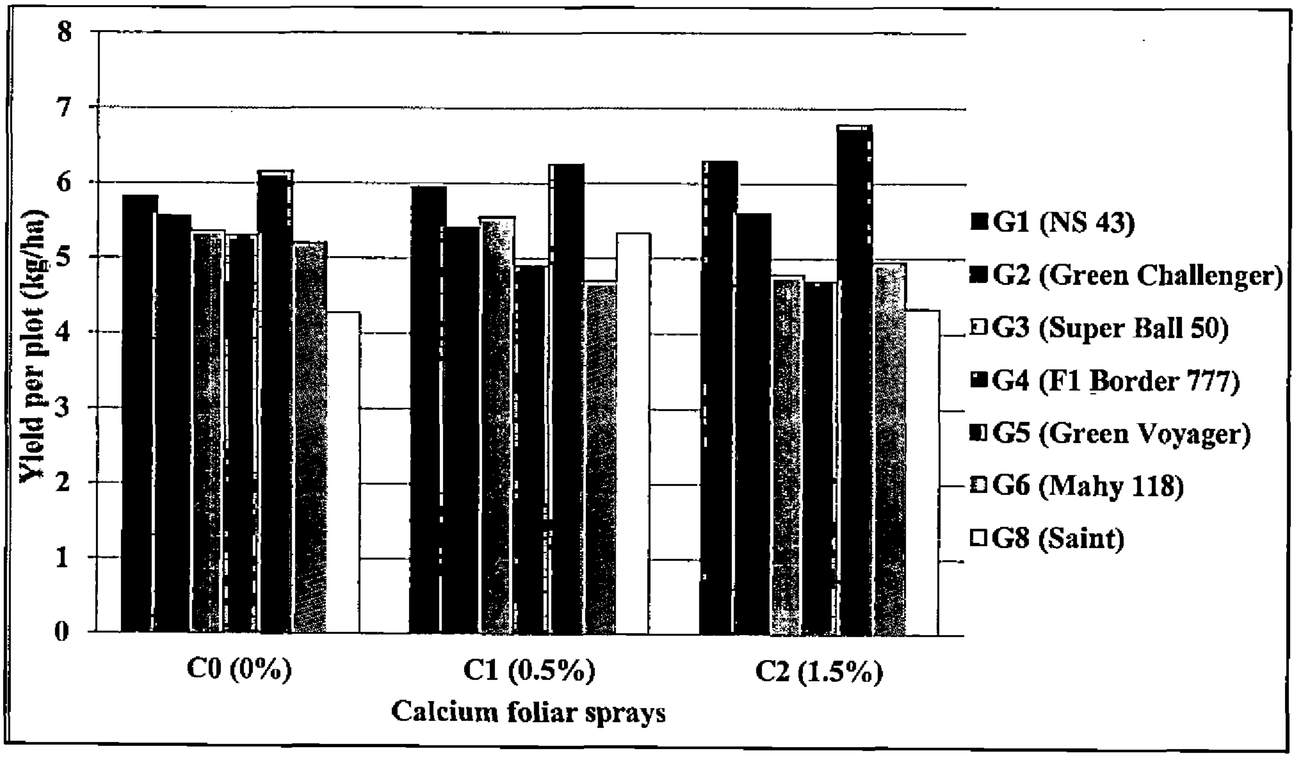

Fig 5.8 Effect of calcium foliar application on yield per plot

The different Ca foliar treatments had no significant difference, the treatment (C_1) (0.5 %) recorded the maximum net head weight (677.14 g) and it was lowest in control treatment (631.28 g). Though there was a non-significant interaction effect on net head weight and different calcium treatments, the maximum net head weight (930 g) was achieved in G_1 C_2 and it was lowest in the interaction G_4 C_1 (524 g). However increase in net head weight increased with Ca foliar application, but this trait also depends on genotypes.

5.2.9 Core length

Core length is measured as the length of the core region of marketable heads. Short core length of less than 25 per cent of head diameter is the most acceptable horticultural trait, which can provide maximum finished product to processors and also consumers (Kleinhenz and Wszelaki, 2003). There is a variation with respect to core length among the cabbage genotypes (Malu, 2011). In the present study, there was a significant difference among the genotypes for core length. The maximum core length (7.88 cm) was recorded in the genotype G_2 (Green Challenger) and it was minimum for genotype G_8 (Saint) (5.80 cm). Similar results were found by (Kurien, 2014). There was no significant difference on core length and planting dates of cabbage during off-season inside rain shelter. The minimum core length (7.08 cm) was recorded in June 15th planting and it was maximum (7.93 cm) in July 15th planting. The cabbage hybrid NS 170 had maximum core length (8.0 cm) at ARS Mannuthy, during on-season (KAU, 2016).

Among the different calcium treatments, the minimum core length (6.35 cm) was recorded in the control (C_0) treatment followed by C_2 with (6.65 cm) and the maximum core length was in the treatment C_1 with (6.89 cm). This shows that core length increase with Ca application. There was no interaction effect among genotypes for core length and calcium foliar application. The interaction G_3 C_0 and G_3 C_2 recorded the minimum core length of 5.50 cm and it was maximum (8.55 cm) in the interaction G_2 C_1.

5.2.10 Head length and head breadth

Head length is a measurement of head index which in turn determines the shape of cabbage heads. Head length is the polar diameter of head at marketable stage. There was no significant difference among genotypes for head length. However the maximum head length of 12.91cm was recorded by the genotype G_1 (NS 43) and the lowest head length (11.56 cm) was in the genotype G_5 (Green Voyager). Kurien (2014) reported that the minimum head length (11.85 cm) was in June 15th planting and it was maximum (13.55 cm) for May 15th planting in the hybrid NS 43 during off- season. The cabbage hybrid Green Voyager recorded the highest head length (15.6 cm) at ARS Mannuthy, during on-season (KAU, 2016). The increased curd length in cauliflower was associated with high rate of photosynthesis form larger leaf area and their translocation towards curd resulting in maximum curd length (Chaurasia *et al.*, 2008).

Foliar application of calcium did not show any significant effect. The treatment mean for head length were on par. The interaction G_4 C_0 recorded the maximum head length of 13.25 cm and it was lowest (10.90 cm) in G_5 C_1. The interaction effect was also non-significant.

Head breadth or equatorial diameter of head was recorded at marketable stage. In the current study, there was significant difference among genotypes for head breadth. The genotype G_1 (NS 43) recorded the maximum head breadth of 13.40 cm and the minimum head breadth was recorded in G_4 (F_1 Border 777) with 9.61 cm. Our findings also closely follows the results found by Malu (2011) who reported that the maximum head breadth was achieved in the hybrid NS 43 (14.05 cm) during off-season and on-season (15.45 cm) inside rain shelter. Similar results were reported by Kurien (2014) for NS 43 who recorded the maximum head breadth of 15.73 cm for May 15th planting during off season inside rain shelter. The cabbage hybrid NS 43 recorded the maximum head breadth of (21.6 cm) in a study conducted at ARS Mannuthy, also during on-season (KAU, 2016). The increased curd breadth in cauliflower is associated with high rate of photosynthesis form larger leaf area and their translocation towards curd resulting in maximum curd breadth. The increase in curd size of cauliflower was due to increase in curd length and curd breadth. This might be due to better crop stand and direct contribution of bio-fertilizers in improving the fertility of the soil because of bacterial activities (Chaurasia *et al.*, 2008).

The different calcium foliar treatments exhibited non-significant difference with respect to head breadth. The treatment C_1 recorded the maximum head breadth (11.33 cm) and other treatments were on par. There was no interaction effect among genotypes for head breadth and different Ca foliar treatments. The maximum head breadth (13.90 cm) was recorded in G_1 C_2 and in the interaction G_4 C_1 (9.60 cm).

5.2.11 Head index

Head index was calculated as the ratio of head length or polar diameter to head breadth or equatorial diameter at marketable stage. Based on the value of head index the head shape will be predicted. Round shaped heads were widely accepted by the consumers and processors in the market over drum head or conical heads with shape index 0.8-1 (Sharma *et al.*, 2006). Singh *et al.* (2010) reported that the higher head index of 0.93 was negatively correlated with lower net head weight (486.25 g). The flat or drum head cabbages produced maximum net head weight over round heads. In the current study, there was significant difference with respect to genotypes for head index. The genotype G_1 (NS 43) recorded the minimum head index of 0.96 and the maximum head index of 1.31 in G_4 (F_1 Border 777). Similar results were reported by Malu (2011) in the hybrid Disha which achieved the maximum head index (1.48) and it was minimum (0.92) for NS 43 during off-season inside rain shelter.

The different calcium foliar treatments showed no significant difference with regard to head index. The minimum head index of 1.10 was recorded in the treatments C_1 and C_2 and it was maximum 1.14 in the control (C_0) treatment. The interaction G_4 C_0 achieved higher head index of 1.37 and it was lowest (0.92) in G_1 C_2. Interaction effect was non-significant among genotypes and different calcium foliar application. However the head index decreased with increased Ca foliar application and the minimum head index was positively associated with maximum yield and net head weight in this study.

5.2.11 Harvest index

Harvest index is the ratio of net head weight (economic yield) to gross head weight (biological yield). Sharma *et al.* (2006) opined that the higher marketable yield has direct correlation with maximum ratio of economical yield to biological yield. In the present study, there was no significant difference among genotypes with respect to harvest index. The maximum harvest index was recorded in the genotype G_8 (Saint) with 69.60 per cent and for the genotype G_5 (Green Voyager) had least harvest index of 66.80 per cent. Singh *et al.* (2010) reported that the cv. Golden Acre recorded the maximum harvest index (74.00) and it was lowest (50.80) in the cv. Ryozeki. The lowest harvest index (53.05) was recorded for June 15th planting and it was highest (60.79) in the May 15th planting in the hybrid NS 43 during off-season (Kurien, 2014).

The different levels of calcium foliar treatments also showed non-significant difference, the maximum harvest index was recorded in the control (C_0) treatment with 68.93 per cent and the lowest harvest index was achieved in the C_1 and C_2 (67.95 %) and (67.62 %) treatments respectively. The interaction G_8 C_1 recorded the maximum harvest index of 74.61 per cent and it was minimum in G_2 C_2 with 62.65 per cent and interaction effect was also non-significant. However the harvest index decreased with increasing Ca foliar application.

5.2.12 Total number of marketable heads per plot

The harvested heads obtained from each plot were sorted into marketable and unmarketable heads (damaged or rotten) based on visual observations. The number of marketable heads from each plot (3.0 m^2 area) comprising twelve plants was recorded as the total number of marketable heads per plot. In the current study, there was no significant difference among genotypes for total number of marketable heads per plot. The genotype G_4 (F_1 Border 777) recorded the maximum number of 11.00 heads per plot and the genotypes G_8 (Saint) and G_2 (Green Challenger) recorded the lowest number of marketable heads (9.00) (Fig 5.7).

The different Ca foliar application showed no significant difference for total number of marketable heads per plot. The control (C_0) treatment recorded the maximum number of marketable heads of 9.92 and it was minimum (9.28) in (C_2) treatment. There was no significant interaction effect with respect to total number of marketable heads per plot. However the maximum number of marketable heads was recorded in G_6 C_1 with 11.50 and it was minimum (7.00) for G_6 C_2 and G_2 C_1 interaction respectively.

Malu (2011) reported that during on-season maximum number (7.75) marketable heads per plot was recorded by the hybrids Disha and NS 35 respectively in open field. The hybrid NS 43 had the maximum number (8.75) marketable heads per plot inside rain shelter during off-season and it closely follows the results reported by Kurien (2014) with the same hybrid NS 43 during off-season. The maximum number of marketable heads was observed on May 15th (16.75) planting and it was minimum (13.25) during July 30th planting. However the number of marketable heads increased with decrease in Ca foliar applications.

5.2.13 Yield per plot

Yield per plot is the net head weight of all the marketable heads from each plot (area 3.0 m^2). Siomos (1999) reported that increased plant densities per unit area had positive correlation with total yield per hectare and it has negative correlation on net head weight and head size. In the present study, there was a significant difference among the genotypes for yield per plot. However the maximum yield (6.40 kg) per plot was recorded in the genotype G_5 (Green Voyager) and it was minimum in G_8 (Saint) with 4.65 kg (Fig 5.8). According to Kurien (2014) the maximum yield per plot was recorded for May 15th planting (11.78 kg) and it was least in June 15th planting (6.13 kg) which was due to lower

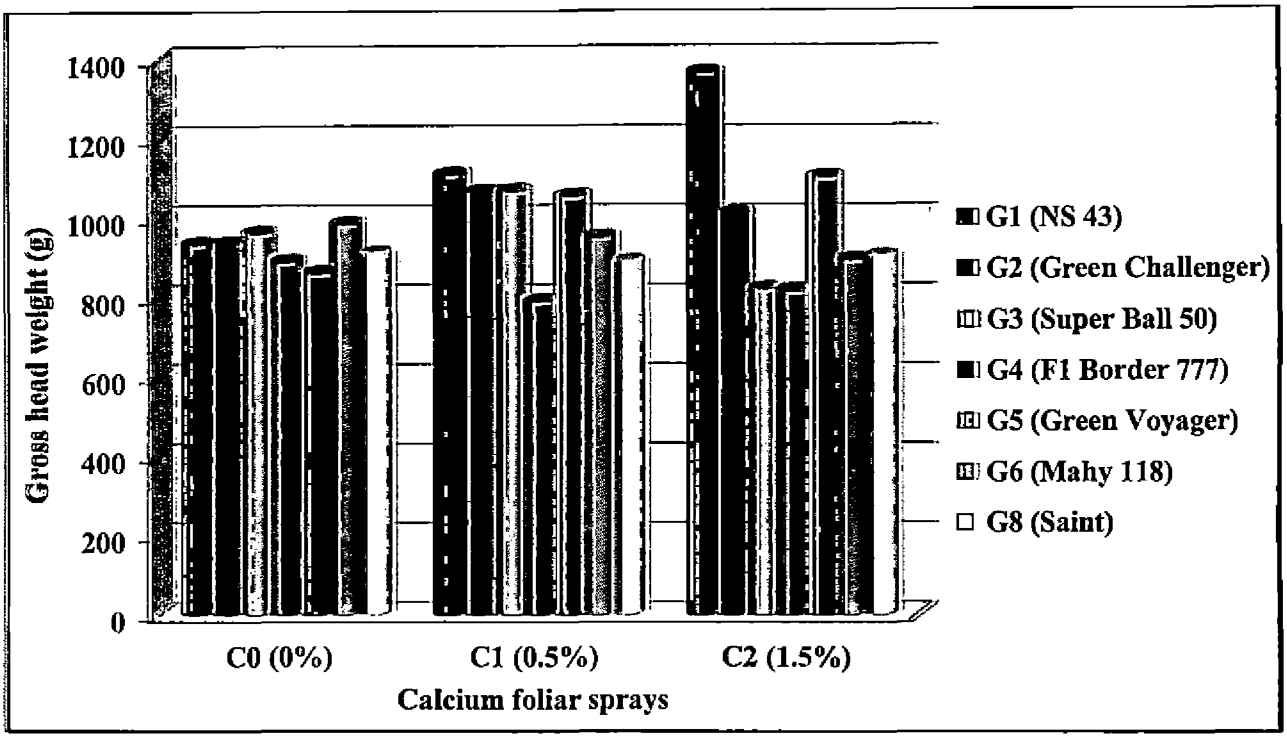

Fig 5.5 Effect of calcium foliar application on gross head weight

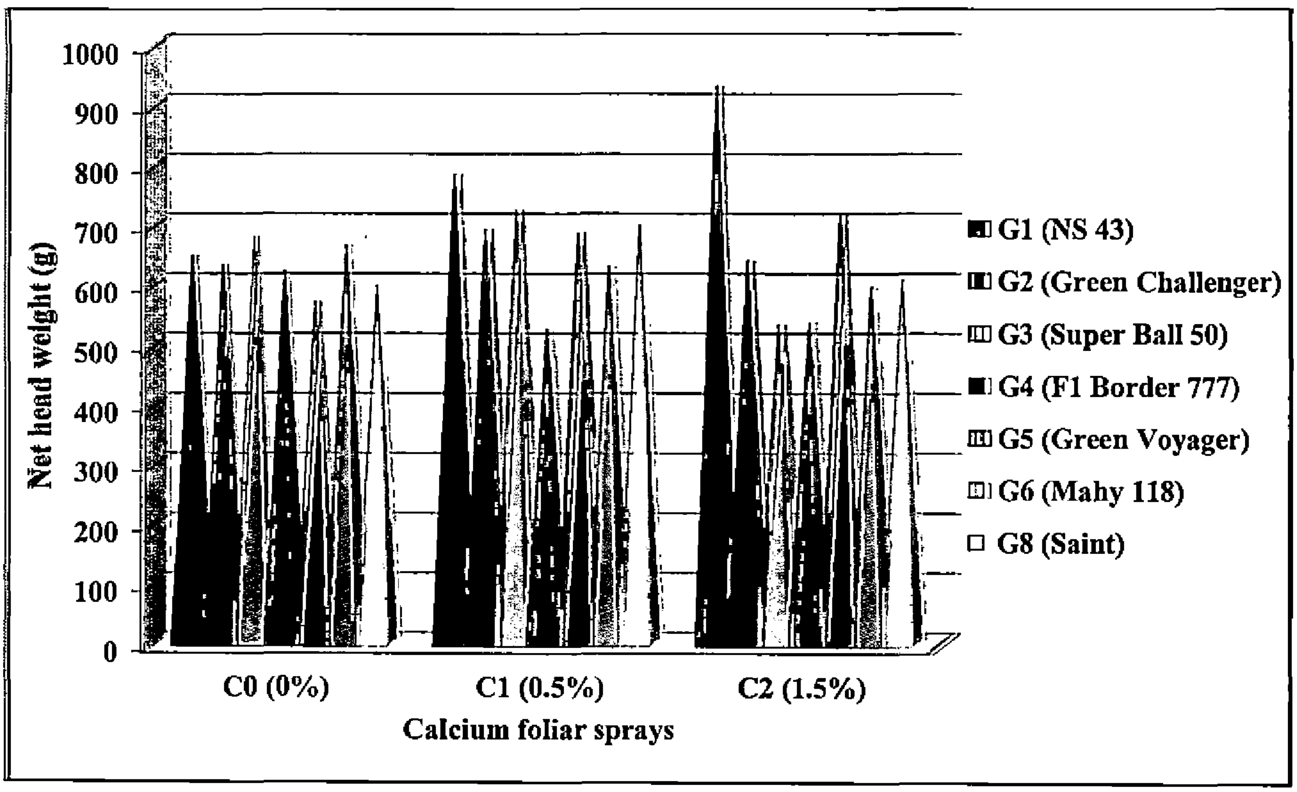

Fig 5.6 Effect of calcium foliar application on net head weight

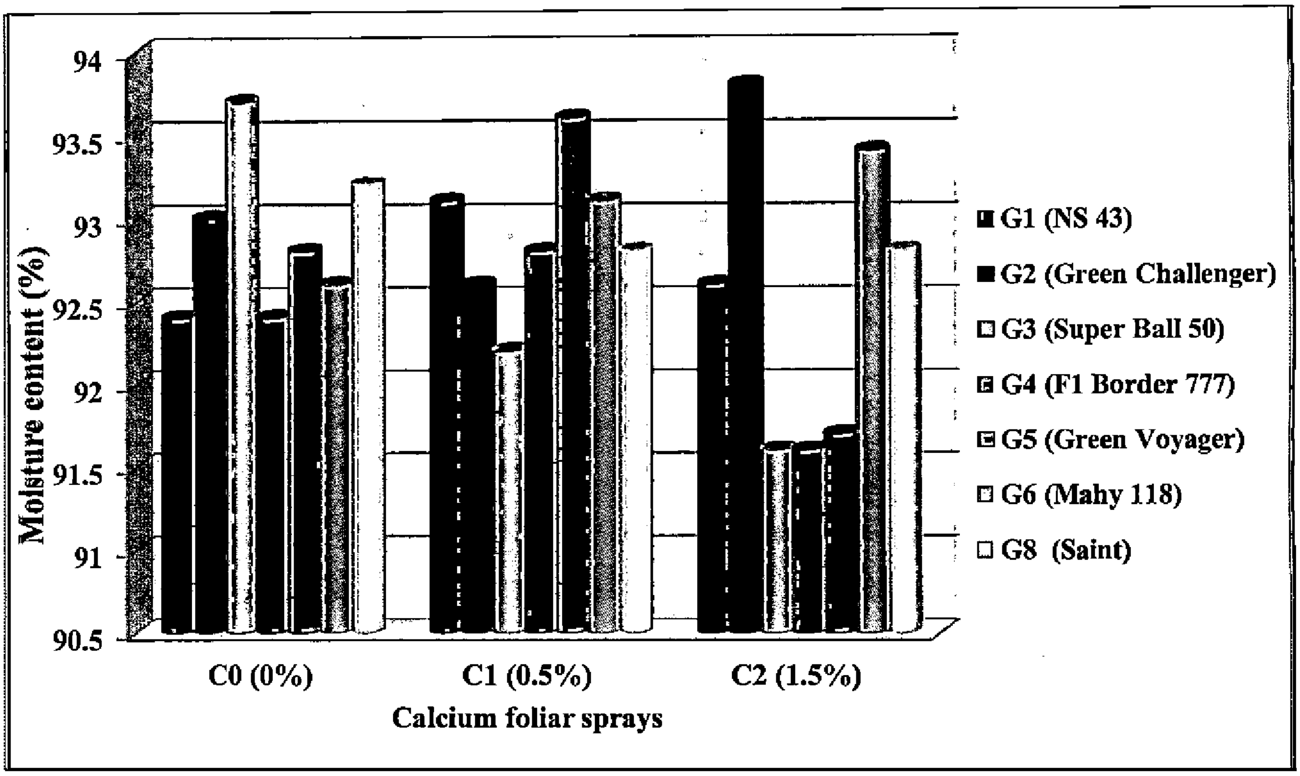

Fig 5.9 Effect of calcium foliar application on moisture content

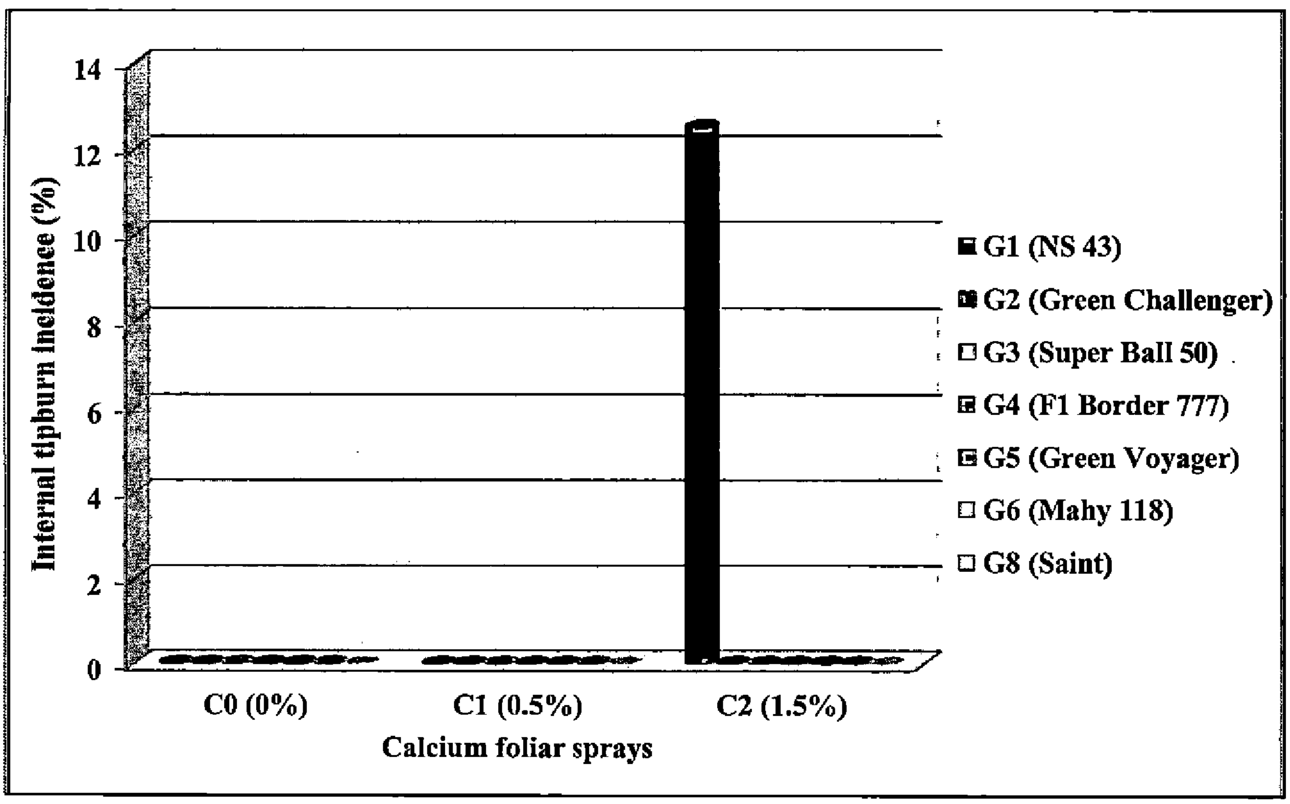

Fig 5.10 Effect of calcium foliar application on internal tipburn incidence

net head weight. Elavarasan (2011) revealed that lower yield of cabbage genotypes in the plains may be due to unfavourable weather conditions that prevailed during the growing season. Nandi and Nayak (2008) reported that the highest yield (377.44 q ha^{-1}) was recorded by 3 foliar sprays of 100 ppm of zinc (as zinc sulphate) followed by 100 ppm copper (as copper sulphate), 100 ppm molybdenum (as ammonium molybdate), 100 ppm iron (as iron sulphate) and the cabbage hybrid Hari Rani Gol. The favourable effects of zinc can be attributed that the element is essential in nitrogen metabolism and it also increases the synthesis of auxin which promotes the cell size which might have increased head weight and ultimately increase yield per hectare (Pal *et al.*, 2004). The increase in the curd yield in cauliflower might be due to the supply of additional nutrients through organic manures as well as improvement in the physical, chemical and biological properties of the soil (Sharma *et al.*, 2005).

The different levels of calcium foliar application exhibited no significant effect, however the maximum yield was recorded in the C_2 treatment with (5.44 kg) and other treatments were on par. The interaction G_5 C_2 showed the maximum yield of 6.79 kg and the lowest yield (4.28 kg) was recorded in G_8 C_0 and interaction effect was also non-significant. Though it was non-significant, yield per plot increased with Ca foliar treatments. The genotype G_5 (Green Voyager) exhibited the maximum yield among genotypes and it increased with the application of Ca (1.5 %) applied. This shows that Ca has a positive influence on total yield.

5.2.13 Moisture content

Moisture content is an indicator of the dry matter content. Higher the moisture content, lower will be the dry matter and vice versa. In the present investigation, there was no significant difference among genotypes for moisture content. The maximum moisture content of 93.13 per cent was recorded in the genotype G_2 (Green Challenger) and it was minimum 92.26 per cent for the genotype G_4 (F_1 Border 777) (Fig 5.9). Our findings are similar with the findings

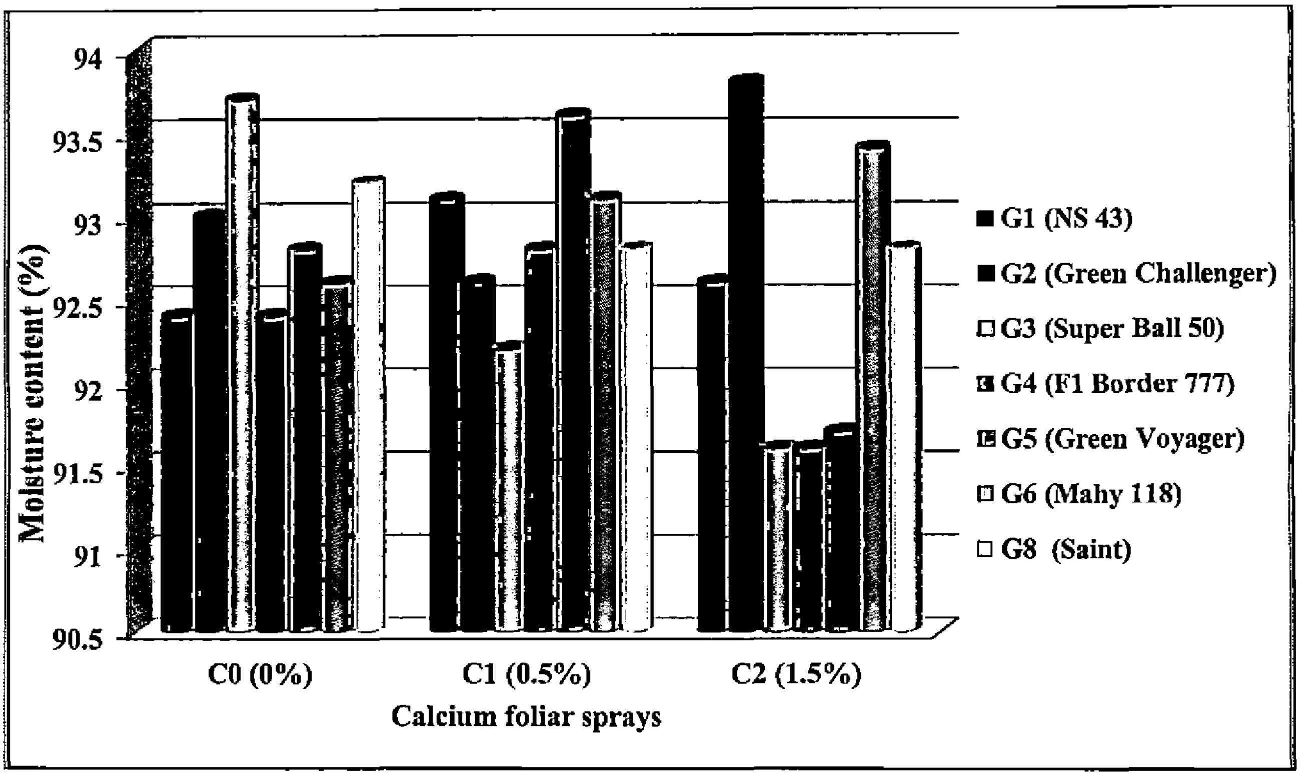

Fig 5.9 Effect of calcium foliar application on moisture content

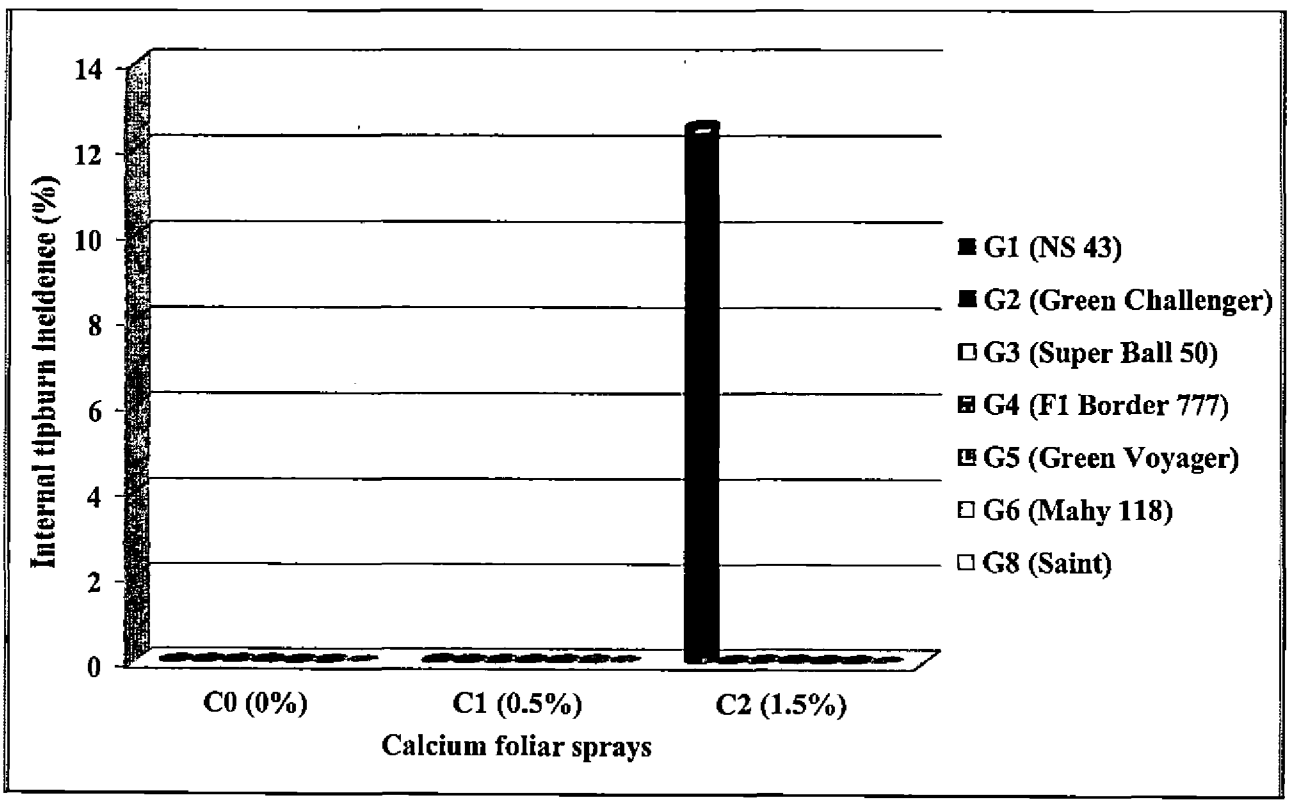

Fig 5.10 Effect of calcium foliar application on internal tipburn incidence

of Chakrabarti (2001) who reported that moisture content in cabbage heads is 92.4 per cent. Kurien (2014) reported that moisture content ranged from 93.41 to 94.69 per cent inside rain shelter during off-season (Kurien, 2014). Moisture content in cabbage was lowest (90.59 %) in on-season crop (winter season) as compared to off-season (rainy season) in the plains of Kerala (Elasavaran, 2011).

The different Ca foliar application showed non-significant difference with regard to moisture content. The treatment C_1 recorded the maximum moisture content of (92.88 %) and other treatments were on par. The interaction effect on moisture content had no significant difference. Interaction G_2 C_2 registered the maximum moisture content of 93.80 per cent and it was minimum (91.60 %) in G_3 C_2 and G_4 C_2 respectively.

5.3 INFLUENCE OF GENOTYPES AND CALCIUM FOLIAR APPLICATION ON PEST AND DISEASE INCIDENCE

5.3.1 Pest incidence

Among the different pests infesting cabbage, *Spodoptera litura* F. is the most important polyphagous pests distributed throughout the south eastern region in the world (Chari and Patel, 1983). Varalakshmi *et al.* (2006) reported that the months of December to January were found ideal for multiplication of *S. litura*. In the present study also tobacco caterpillar, snail and flea beetle were noticed inside rain shelter during off-season. There was no significant difference among genotypes for percentage of pests incidence. However the maximum pest incidence of 9.72 per cent was recorded in the genotypes G_2 (Green Challenger) and G_8 (Saint) respectively and the lowest pest incidence (5.55 %) was in G_4 (F_1 Border 777) (Fig 5.11). Similar results were reported by Malu (2011) who observed that the tobacco caterpillar (*Spodoptera litura* F.) as the major pest on cabbage during off-season inside rain shelter. Kurien (2014) also revealed that under Kerala climatic conditions, the major pest was tobacco caterpillar (*Spodoptera litura* F.) in all the planting dates during off-season inside rain shelter. These caterpillars severely feed on cabbage heads and finally these infested heads become unmarketable. The highest percentage of pest incidence (23.75 %) was recorded for July 30th planting and it was least (8.75 %) in May 15th planting. Slug and snail infestation was observed after rains on spring cabbage and Chinese cabbage (Mundane and Bailey, 1989).

The different levels of calcium foliar application have no significant difference on pest incidence. The maximum pest incidence (10.71 %) was recorded in the treatment C_2 (1.5 %) and it was minimum in C_1 (0.5 %) with 5.95 per cent. The interaction effect and different Ca treatments exhibited non-significant difference. interaction G_7 C_2 recorded maximum pest incidence of 16.66 per cent and it was minimum (4.16 %) in G_1 C_1, G_4 C_1 and G_5 C_2 interactions. However the increased Ca foliar application showed increased percentage of pest incidence during off-season inside rain shelter.

5.3.2 Disease incidence

In the present experiment, different diseases observed were soft rot (*Erwinia caratovora*), damping-off (*Pythium sp.*) and head rot inside rain shelter during off-season. When Chinese cabbages were grown at high temperature conditions soft rot (*Erwinia caratovora*) and tip burn incidence were very severe (Kuo and Tsay, 1981). According to Dohroo (2001) increased soil moisture and temperature enhanced the development of damping-off disease caused by (*Pythium sp.*) in seedling nursery which increased the rate of seedling mortality in all the cultivars. The incidence of soft rot disease caused by the bacteria (*Erwinia carotovor*) was positively correlated with higher humidity (Singh, 2007). There was no significant difference among the genotypes for percentage of disease incidence. The maximum disease incidence of 9.71 per cent was recorded in genotypes G_1 (NS 43) and G_8 (Saint). Genotypes G_5 (Green Voyager) and G_6 (Mahy 118) had lowest disease incidence of 4.16 per cent (Fig 5.12). Similar results were reported by Kurien (2014). The maximum disease incidence (11.25 %) was observed for June 30th planting and it was lowest (3.75 %) for May 15th

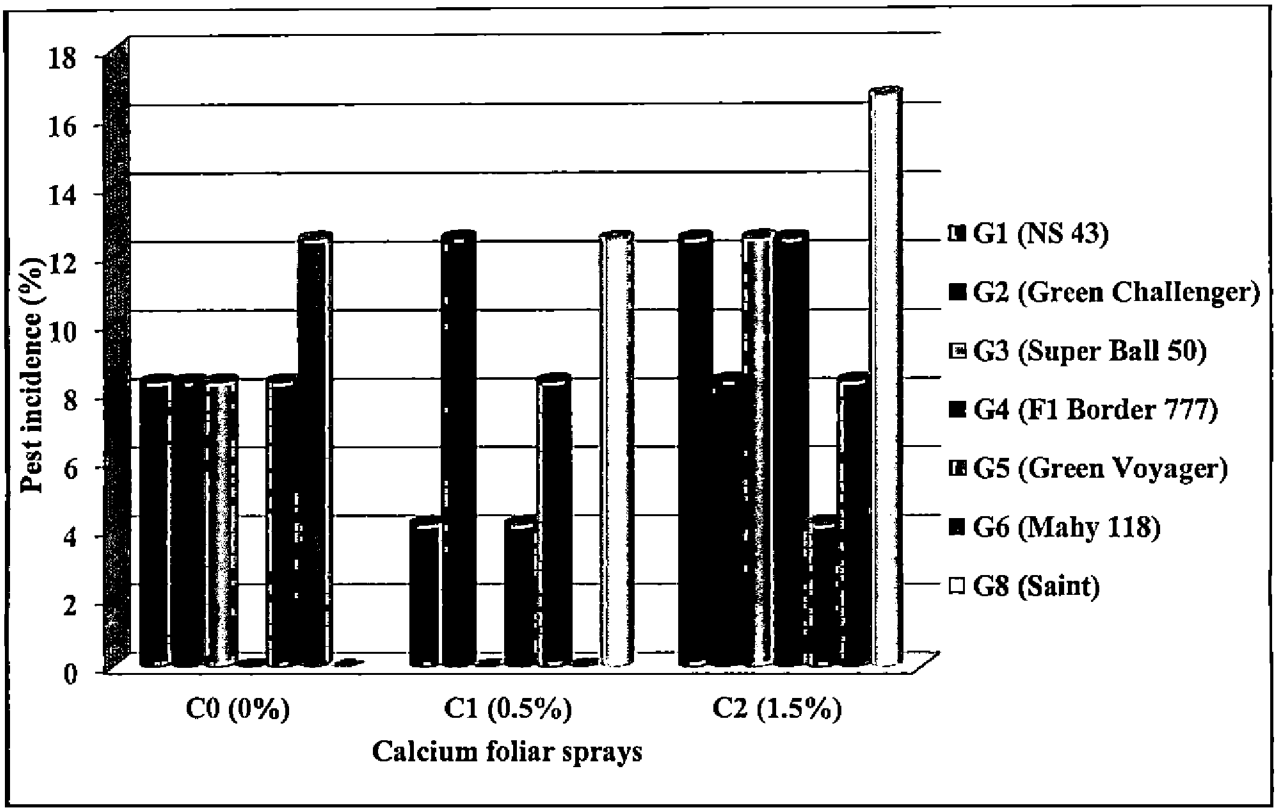

Fig 5.11 Effect of calcium foliar application on pest incidence

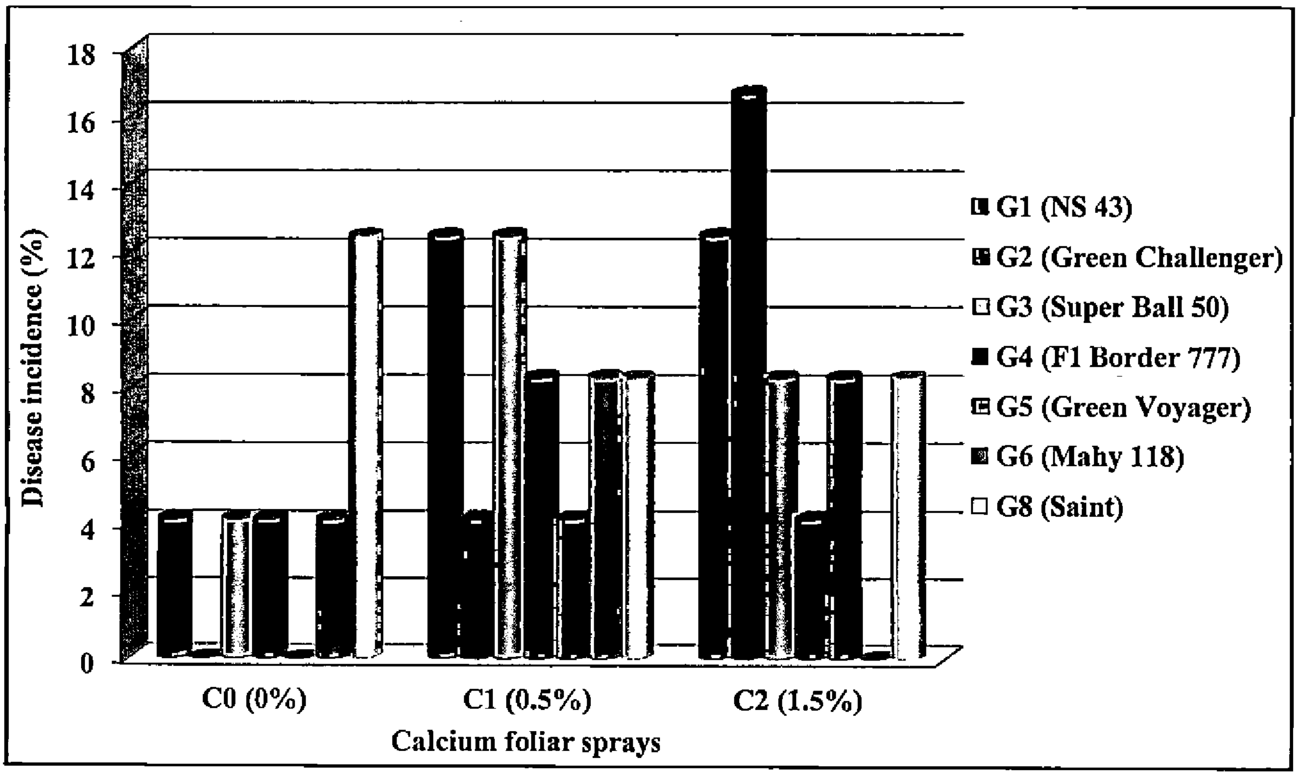

Fig 5.12 Effect of calcium foliar application on disease incidence

planting. The soft rot (*Erwinia carotovora*) affected heads were completely unmarketable (Kurien, 2014).

There was no significant variation for different Ca application with respect to disease incidence. The treatment C_2 recorded the maximum disease incidence of 10.71 per cent and and it was minimum in C_1 and C_0 treatment of 5.95 per cent and 6.54 per cent respectively. Interaction effect also showed non-significant difference with regard to different Ca treatments and disease incidence. Interactions G_4 C_0, G_6 C_0, G_3 C_0, G_1 C_0, G_4 C_2, G_5 C_1 and G_2 C_1 respectively recorded the lowest disease incidence of 4.16 per cent and it was maximum of 16.66 per cent in G_2 C_2 interaction. However the increased Ca foliar application was showed higher percentage of pest incidence. However the increased Ca foliar application showed increased percentage of disease incidence during off-season inside rain shelter.

5.4 INFLUENCE OF GENOTYPES AND CALCIUM FOLIAR APPLICATION ON INTERNAL TIPBURN INCIDENCE

Internal tipburn is a calcium related physiological disorder which is caused by a localized Ca deficiency in the leaf tip. Poovaiah (1988) reported that deficiency of Ca causes membrane leakage, dissolution of the middle lamella and associated changes in the cell wall. The tissues with higher rate of transpiration receive larger amounts of calcium than low transpiring tissues (Epstein, 1972). When transpiration rate is reduced, root pressure is able to drive water and solutes through the plant in the xylem (Henzler *et al.,* 1999). Root pressure plays a major role in transporting calcium to tissues that do not receive sufficient calcium through transpiration. Root pressure helps in preventing Ca related disorders in enclosed organs in cabbage heads, where growth related calcium demand is high and transpiration is low (Palzkill and Tibbitts, 1976). The inward cupping and marginal burn of the young leaves of collard appeared to be similar to that associated with tipburn on cabbage and cauliflower (Maynard *et al.,* 1981). Tip burn is a common problem in leaves of several vegetables especially cabbage, Chinese cabbage, lettuce and coriander, which may lead to substantial yield loss.

Symptoms of tipburn include leaf browning followed by necrosis at the leaf margin of younger leaves and affected tissues become water soaked (Chang and Miller, 2005). High GA_3 levels in plants reduce Ca activity in the cell wall, thus increase growth rate associated with higher demand of Ca to actively growing and developing young leaves (Moll and Jones, 1981). A sudden raise in temperature after prolonged period of lower temperature increase the risk of tipburn in greenhouse grown cabbage or increase in temperature associated with low relative humidity also induce tipburn (Aloni, 1986). According to Imai (1987) high N supplementation in the form of ammoniacal nitrogen, especially during head formation stage in cabbage increases the incidence of tipburn over the nitrate nitrogen. Van Berkel (1988) found that higher relative humidity in the night is associated with low transpiration rate which can minimize the tipburn incidence in cabbage. Kurien (2014) also reported that the incidence of internal tipburn in off-season cultivation. Hence in the present study Ca foliar application was given to find out its effect on internal tipburn incidence.

In the present study, there was no significant difference with respect to genotypes or different levels of calcium foliar treatments for internal tipburn incidence. Among the seven genotypes, only the genotype G_1 (NS 43) recorded a slight incidence of tipburn (4.16 %). Among the different Ca foliar application, only in the (C_2) treatment slight incidence of tipburn was noticed with 1.78 per cent (Fig 5.10). Interaction effect was also non-significant, only the interaction G_1 C_2 recorded 12.50 per cent of tipburn over the other interactions. Our findings were in line with the results presented by Rosen (1990) who reported that the best method to control tipburn of cauliflower was to use resistant cultivars. Soil application of $CaSO_4$ or foliar application of $Ca(NO_3)_2$ or $CaCl_2$ did not decrease the incidence of tipburn in the collard cv. Vates as reported by Johnson (1991). The best method to control tipburn of collards grown during the summer in the south eastern United States was the use of tolerant cultivars. In the present study also only the genotype NS 43 was susceptible. All others were resistant. There are also reports that susceptibility to tipburn is genetically determined and the use of

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resistant cultivar is the possible way to reduce the incidence of this disorder (Rana, 2008). Kurien (2014) also reported that the incidence of tipburn and necrosis for the first time in NS 43.

Barta and Tibbitts (1991) revealed that plants grown inside greenhouse are severely affected by tipburn than field grown plants, though greenhouse grown plants receive only half of the light intensity than the latter. There was significant difference among tipburn incidence for different planting dates. Planting of cabbage on March 8th with Nitro-Plus (nutrient mixture) foliar treatment recorded the maximum tipburn incidence due to restricted root growth as compared to urea foliar treatment (Vavrina and Obreza, 1992). According to Borkowski and Szwonek (1994) the foliar applications of Ca cannot minimize the incidence of tipburn. The applied Ca will not reach the tipburn sensitive tissues. Here also in C_2 treatment even though 1.5% Ca was given as foliar spray, those heads only showed internal tipburn. Stromme *et al.* (1994) revealed that the foliar application of Ca essentially prevented bract necrosis in Poinsettia. But, waxy layer on the leaf surface of *Eustoma* sp. may restrict the Ca absorption through the cuticle as found by Islam *et al.* (2004). Gaudreau *et al.* (1994) reported that the incidence of tipburn increased with the light intensity and long photoperiods. Thibodeau and Minotti (1969) revealed that shading may reduce the incidence of tipburn. Increased EC in the nutrient solution may reduce water uptake and limit the Ca transport to young developing leaves. The leaf vein and leaf margins became yellow in butter head lettuce (Choi and Lee, 2001). A reduction in the relative humidity is more important to reduce the incidence of tipburn than adding more Ca to the nutrient solution (Torre *et al.* 2001). In the present study also the relative humidity ranged from 80-89 per cent inside rain shelter (Appendix I). This condition might have reduced the internal tipburn incidence inside rain shelter. The incidence and severity of tipburn in *Eustoma* sp. increased with increasing RH, although the cultivars differed in sensitivity. Sensitive cultivars easily affected by tipburn at high RH or only few hours high RH at night may cause tipburn incidence (Islam *et al.*, 2004). The increased relative humidity of 90-95 per cent showed lesser Ca content in tomato plants and the low relative humidity 70-75 per cent was associated with increased Ca content (Gislerod *et al.,* 1987). Increasing air humidity reduces transpiration rate and transport of Ca (Ehret and Ho, 1986), which may lead to Ca deficiency symptoms in the upper and rapidly expanding leaves (Winsor and Adams, 1987).

5.5 BENEFIT COST RATIO

Farmer will adopt a new technology only when it is remunerative. Studies on the year round cauliflower production in open and under cover conditions in the hills of Darjeeling district revealed that cultivation inside high cost poly house is not feasible in the region due to high erection cost and very low wholesale price. Compared to protected conditions the benefit-cost ratio was higher in open conditions during winter and summer (Pradhan *et al.,* 2008). In the present study also, total cost of cultivation was Rs. 68.99 per m^2 and total benefit varied from Rs. 84.60 to 105.48 per m^2 among genotypes. The maximum benefit-cost ratio of 1.52 was recorded in the G_5 (Green Voyager) and it was minimum (1.22) in G_8 (Saint). However labour charges accounted was 70.15 per cent and construction or maintenance of structure accounted only 18.11 % of the total cost. Similar findings were reported by Pandey *et al.* (2001) who revealed that the cost of cultivation off-season cabbage in Shimla was Rs. 34880/ha with a benefit-cost ratio of 1.4 and the maximum contribution to costs was by human labour 43.3 per cent.

The highest benefit-cost ratio of 1.14 was recorded during off-season inside rain shelter (Malu, 2011). Kurien (2014) also reported that the minimum benefit-cost ratio was recorded in May 30th planting (0.67) and it was maximum for May 15th planting with 1.2. The total cost of cultivation ranged from Rs. 41.73 to 75.21 per m^2 on different planting dates. Hence growing of off-season cabbage inside rain shelter will provide an opportunity to get extra income to farmers. Labour charges can be minimized by adopting family labour and effective utilization of on farm resources. Being an off-season crop, if the farmer is getting a premium price it will be highly remunerative also.

5.6 SOIL NUTRIENT STATUS

Soil nutrient status was studied before raising the crop and after the crop harvest. Diferent parameters like pH, Organic carbon, available P, K, Ca, Mg, Fe and Mn content were studied. For nutrient analysis only the genotype G_1 (NS 43) which was susceptible to internal tipburn and the resistant genotype G_5 (Green Voyager) were selected and plant samples were analysed for N, P, K, Ca, Mg, Fe and Mn content in both leaf and heads. The results are discussed below.

5.6.1.1 Soil pH

Mahendra *et al.* (1988) reported that there was no significant difference by the application of organic or inorganic fertilizer on soil pH. Application of gypsum as Ca source to soil also not influenced the soil pH (Scott *et al.,* 1993). In the present study, there was no significant difference with respect to soil pH before raising the crop. The soil pH of experimental plots ranged from 5.30 to 5.85.

No significant variation was observed among the genotypes with respect to soil pH after the crop harvest. The genotypes G_1 (NS 43) and G_5 (Green Voyager) recorded the soil pH 5.23 and 5.29 respectively. The addition of lime to soil may increase the pH of experimental plots ranging from 7.18 to 8.21 (Swiatkiewicz and Sady, 2010).

Bonomelli and Ruiz (2010) reported that after the foliar and soil application of $CaCl_2$ on grape, the soil pH ranged from 6.90 to 7.21 after the crop harvest. Different calcium foliar treatments and interaction effect were non-significant with respect to soil pH. The treatment C_2 (1.5 %) recorded maximum soil pH (6.07) and other treatments were on par. The interaction G_1 C_2 recorded the maximum soil pH of 6.90 and it was lowest in G_1 C_0 (4.29). However increased Ca application is associated with increase in soil pH over control treatment.

5.6.1.2 Organic carbon

In the present investigation, there was no significant variation in soil organic carbon among the earmarked plots before raising the crop, which ranged from 1.75 to 1.85 per cent. The low usage of organic manures and heavy chemical fertilizer application leads to depleted organic carbon and also high temperature during summer might be responsible for the rapid burning of organic matter. Genotypes exhibited a significant variation with respect to organic carbon. The genotype G_5 (Green Voyager) recorded the maximum organic carbon of 1.93 per cent and for G_1 (NS 43) it was only (1.59 %) after raising the crop. Different levels of foliar sprays of Ca and interaction effect also did not show significant variation in terms of organic carbon in soil.

5.6.1.3 Available phosphorus

In the present study, there was no significant difference with respect to available P in the soil. The available P in the soil ranged from 81.61 to 161.05 kg ha^{-1} before raising the crop. Only 25% of recommended phosphorus fertilizer was applied based on initial soil test report. Genotypes showed non-significant difference with regard to available P in soil. Different levels of Ca foliar spray and interaction effect also did not show significant difference with respect to the availability of P in soil.

Similarly Rajeshwar *et al.* (2009) also revealed that the availability of phosphorus in the soil ranges from 5.3 to 33.4 kg ha^{-1} and surface soils had higher P availability than sub-surface soils. The low to medium P availability in soil might be due to past fertilization and agronomic practices. If the water soluble P is applied to soil it readily convert into insoluble P by reacting with Ca and Mg ions. Fertilization of $(NH_4)_2SO_4$ to neutral soils increase the availability of phosphorus to plants by acidification of rhizosphere.

5.6.1.4 Available potassium

In the present investigation also there was no significant variation among the plots with respect to available potassium in soil. The availability of potassium ranged from 249.20 to 285.60 kg ha^{-1}. Only 75% of recommended potassium fertilizer was applied based on initial soil test report. Similar results were reported by (Mathew, 2013). The available potassium in the soil was 160.50 kg ha^{-1} before foliar nutrition and it was 165.54 kg ha^{-1} after the harvest of mangosteen fruits. The availability of potassium in soil depends on the nature and type of clay mineral. The K fixation process was faster in high soil pH as compared to neutral soil (Bolan *et al.,* 1999).

Different levels of Ca foliar spray showed non-significant difference with respect to K availability. The interaction effect showed significant variation with different levels of Ca foliar spray. The interaction G_1 C_1 had highest available K with 492.80 kg ha^{-1} and it was minimum in G_1 C_2 (203.84 kg ha^{-1}) after the crop harvest.

5.6.1.5 Available calcium

In the present study, there was no significant difference with respect to available Ca. The available Ca ranged from 816.25 to 954.12 mg kg^{-1} before raising the crop. Similar results were found by Mathew (2013) who reported that availability of Ca in soil before foliar application was 219 mg kg^{-1} and it was reduced to 190 mg kg^{-1} after the harvest of mangosteen.

No significant variation was observed among the different genotypes with respect to available Ca in soil. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Ca content in soil after the crop harvest. Scott *et al.* (1993) also reported that the soil application of Ca had no significant effect on watermelon yield (31 to 37 t ha^{-1}) for all the three cultivars. In treatment where Ca was applied at 1120 kg ha^{-1} gave lower fruit weight of 9.22 kg as compared to melons grown at 560 kg ha^{-1} which gave higher fruit weight of 9.56 kg.

5.6.1.6 Available magnesium

In the present study, there was no significant difference with respect to the availability of magnesium. The available soil Mg ranged from 169.50 to 239.25 mg kg^{-1} before raising the crop. Bonomelli and Ruiz (2010) revealed that the availability of Mg in the soil was 4.9 mg kg^{-1} before Ca foliar application on the grape cv. Thompson seedless. Mathew (2013) also reported that the availability of soil magnesium was 143.04 mg kg^{-1} before foliar applications and it was 133.85 mg kg^{-1} after the fruit harvest of mangosteen.

Genotypes showed non-significant variation with regard to available Mg in soil. Different levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Mg content in soil after the crop harvest.

5.6.1.7 Available iron

There was no significant difference with regard to available soil Fe. The available iron in soil was ranged from 29.96 to 31.77 mg kg^{-1} before raising the crop. Bonomelli and Ruiz (2010) also reported that the available Fe in soil before Ca foliar application on the grape cv. Thompson Seedless was 8.8 mg kg^{-1}.

No significant variation was observed among different genotypes. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Fe content in soil after the crop harvest

5.6.1.8 Available manganese

In the present investigation, the available soil Mn ranged from 46.13 to 51.33 mg kg^{-1} before raising the crop. Bonomelli and Ruiz (2010) also reported that the available Mn in soil was 6.9 mg kg^{-1} before Ca foliar application on grape cv. Thompson seedless.

Genotypes showed non-significant variation with respect to available Mn in soil. Levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of available Mn content in soil after the crop harvest.

5.6.2 Nutrient content in leaf and head at harvest

5.6.2.1 Nitrogen content in leaf

In the present study there was no significant variation between treatments among different genotypes. Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of nitrogen content in leaf. The foliar application of urea at 1.0 per cent on broccoli cv. AG 3324 recorded the higher nitrogen content in leaf (3.33 %) over the control treatment (2.9 %) as reported by Yildirim *et al.* (2007). There was a significant difference for foliar application of urea at (0.5 %) on mangosteen which increased the nitrogen content in standard leaf (Mathew, 2013). Swietlik and Faust (1984) also revealed that the foliar application of $CaCl_2$ in combination with urea will enhance the nitrogen content in apples leaves.

5.6.2.2 Nitrogen content in head

In the present investigation also, there was no significant difference among the genotypes with respect to nitrogen content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of nitrogen content in head. Yildirim *et al.* (2007) revealed that the foliar application of urea at 1.0 per cent on broccoli cv. AG 3324 recorded the maximum nitrogen concentration in head (3.90 %) over the control treatment (2.02 %).

5.6.2.3 Phosphorus content in leaf

Generally phosphorus content in cabbage leaves ranged from 0.34-0.58 per cent (Barker and Pilbeam, 2006). In the present experiment, genotypes exhibited non-significant difference with respect to phosphorus content in leaf.

Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of phosphorus content in leaf. Yildirim *et al.* (2007) reported that the foliar application of urea at 1.0 per cent on broccoli cv. AG 3324 recorded the maximum value of 0.48 per cent phosphorus content in leaf and it was minimum (0.30 %) in control treatment. This might be due to lower application of phosphorus only 75% recommended dose of fertilizer (RDF) was applied.

5.6.2.4 Phosphorus content in head

Genotypes showed non-significant variation with respect to phosphorus content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of phosphorus content in head.

5.6.2.5 Potassium content in leaf

Barker and Pilbeam (2006) revealed that the potassium content in *Brassica* species ranged from 3-4 per cent. In the present experiment, there was no significant variation between treatments with different genotypes. Levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of potassium content in leaf. Scott *et al.* (1993) revealed that leaf K content in watermelon cultivar 'Tri-X Seedless' recorded the maximum potassium of 2.10 per cent followed by 'Charleston Gray' (1.68 %) and it was lowest (0.68 %) in 'Crimson Sweet'. Foliar fertilization of potassium nitrate on Clementine mandarin increased the potassium concentration in leaves (Hamza *et al.*, 2012). Foliar application of KNO_3 at (2.0 %) significantly increased the potassium content in mangosteen leaves (Mathew, 2013).

5.6.2.6 Potassium content in head

Genotypes showed non-significant variation with respect to potassium content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of potassium content in head. Scott *et al.* (1993) revealed that potassium content in the rind of watermelon cultivars

'Tri-X Seedless' and 'Crimson Sweet' were 8.0 % and 7.3 % respectively. The cultivar 'Charleston Gray' recorded lower K content (6.84 %).

5.6.2.7 Calcium content in leaf

The optimum Ca concentration in *Brassica* species ranged from 0.1-5 per cent (Barker and Pilbeam, 2006). In the present experiment, there was no significant variation between treatments with different genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of calcium content in leaf. There was a significant difference in Ca content in leaf by foliar sprays of one per cent urea on broccoli cv. AG 3324 which recorded maximum leaf Ca concentration (0.70 %) and in control treatment it was only (0.59 %) (Yildirim *et al.,* 2007). Neilsen *et al.* (1993) also reported that the apple trees fertigated with $Ca(NO_3)_2$ recorded the maximum (1.23 %) leaf Ca as compared to band application which recorded the lowest (1.21 %) leaf Ca in apple cv. Jonagold. Barker and Pilbeam (2006) reported that the soil application of lime increased calcium content in cabbage leaves.

5.6.2.8 Calcium content in head

Genotypes exhibited non-significant variation with respect to calcium content in head. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of calcium content in head. Scott *et al.* (1993) reported that the total Ca accumulation in rind tissue at blossom end of watermelon recorded lower (0.70 %) Ca for 560 kg ha^{-1} gypsum applied and it was highest (0.84 %) for 1120 kg ha^{-1}. Qiu *et al.* (1995) also reported that the foliar application of $CaCl_2$ (2.0 %) at weekly intervals on papaya seedlings showed a significantly higher Ca content in the outer mesocarp (187 $\mu g\ g^{-1}$ FW) than in inner mesocarp (127 $\mu g\ g^{-1}$ FW). Only the genotype G_1 (NS 43) showed symptoms of tipburn which showed that susceptibility to this disorder is genotype specific. That is why these symptoms were reported by Kurien (2014) also in NS 43. This study also supports her findings.

5.6.2.9 Magnesium content in leaf

Barker and Pilbeam (2006) also reported that optimum magnesium concentration in *Brassica* species ranged from 0.17-1.08 per cent. Genotypes showed non-significant variation with respect to magnesium content in leaf. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of magnesium content in leaf. Scott *et al.* (1993) reported that magnesium content in leaf of watermelon cultivars varied. The cultivar 'Crimson Sweet' recorded 0.70 per cent of leaf Mg than in cultivars 'Chrleston Gray' and 'Tri-X-Seedless' recorded lower magnesium concentration in leaf (0.59 %) and (0.51 %) respectively.

5.6.2.10 Magnesium content in head

No significant variation was observed with respect to magnesium content in head among the different genotypes. Different levels of foliar spray of Ca and interaction effect also did not give any significant difference in terms of magnesium content in head. Yildirim *et al.* (2007) also reported that foliar application of urea (1.0 %) on broccoli cv. AG 3324 recorded the higher Mg content in head (0.28 %) over the control treatment with 0.17 per cent.

5.6.2.11 Iron content in leaf

Genotypes exhibited non-significant variation with regard to iron content in leaf. Different Ca foliar treatments and interaction effect also did not give any significant difference in terms of iron content in leaf. Scott *et al.* (1993) reported that after the soil application of gypsum, the cultivar 'Crimson Sweet' of watermelon recorded the maximum concentration of Fe in leaf (126 ppm), 'Charleston Gray' and 'Tri-X-Seedless' recorded lower iron content in leaf (111 ppm) and (113 ppm) respectively.

5.6.2.12 Iron content in head

There was no significant variation with respect to iron content in head among the genotypes. Different levels of Ca foliar application and interaction effect also did not give any significant difference in terms of iron content in head. Foliar application of urea (1.0 %) on broccoli cv. AG 3317 recorded the maximum head Fe 103 ppm and the control treatment recorded only 79.00 ppm (Yildirim *et al.,* 2007).

5.6.2.13 Manganese content in leaf

In the present experiment there was a significant difference among the genotypes with respect to manganese content in leaf. The mean value of genotype G_1 recorded maximum manganese content in leaf (57.71 ppm) followed by G_5 with 44.43 ppm. There was significant difference with different levels of Ca foliar treatments. The treatment (C_1) had higher (55.97 ppm) manganese content in leaf followed by treatments C_0 and C_2. There was a interaction effect with respect to genotypes and different levels of calcium foliar application. There was a significant difference among genotypes and Ca foliar sprays with respect to manganese content in leaf. The interaction G_1 C_1 recorded higher manganese content in leaf with 69.80 ppm followed by interaction G_1 C_2, G_5 C_2, G_1 C_0 and G_5 C_1. The manganese content in leaf was lesser in G_5 C_0 interaction with 39.10 ppm. Schreiner *et al.* (2006) also reported that the increased Mn content in leaf of the grape cv. 'Pinot Noir' is mainly due to high Mn concentration (25 to 30 mg) in the leaf blades at harvest. Application of gypsum to soil, recorded the higher leaf Mn (182 ppm) in 'Crimson Sweet' cv. than 'Chrleston Gray' and 'Tri-X-Seedless'. They recorded lower concentration of leaf Mn (138 ppm) and (122 ppm) respectively (Scott *et al.,* 1993).

5.6.2.14 Manganese content in head

Genotypes showed significant difference with respect to Mn content in head. The genotype G_1 recorded higher manganese (49.53 ppm) in head followed by G_5 with 36.26 ppm. Different levels of foliar sprays of Ca and interaction effect also did not give any significant difference in terms of manganese content in head. Yildirim *et al.* (2007) reported that the foliar application of urea (1.0 %) on broccoli cv. AG 3317 recorded the increased head manganese content of 37 ppm over the control treatment (22 ppm).

Conclusion

In the present investigation the genotype G_5 (Green Voyager) produced very compact heads, with high gross head weight (1005.83 g), yield per plot (6.40 kg), resistance to internal tipburn and high benefit-cost ratio (1.52). Hence this genotype can be recommended for off-season cultivation under rain shelter in the central plains of Kerala. From the present study it was found that internal tipburn is a genotype specific disorder and it cannot be reduced by Ca foliar application. Earlier studies also indicated that NS 43 is susceptible to this disorder. There are also reports that it is a genetically determined character. Hence more number of genotypes are to be screened for resistance to internal tipburn. Though Ca foliar application can minimise the incidence of internal tipburn, it increased the yield in genotypes G_1 (NS 43) and G_5 (Green Voyager), when compared to control treatment and it showed that Ca foliar application has a positive influence on yield.

The Ca foliar treatments on cabbage increased the available calcium and magnesium in the soil. There was also increase in the leaf phosphorus, leaf calcium, leaf magnesium and leaf manganese, while other nutrients like nitrogen, potassium and iron showed not much variation both in soil as well as in the leaf and head.

Future line of work

The experiment has to be repeated for the confirmation of results. Since internal tipburn is a genotype specific calcium deficiency disorder, more number of cabbage genotypes are to be included in the further studies. Though off-season cabbage cultivation is feasible, high yielding genotypes are to be identified.

SUMMARY

6. SUMMARY

The present investigation was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during the rainy season (May-September) of the year 2015. The objectives were evaluation of cabbage (*Brassica oleracea* L. var. *capitata*) genotypes for compactness and internal tipburn resistance under rain shelter. The experiment was laid out in randomized block design with two replications. The treatments comprised of three levels of calcium foliar sprays (0 %, 0.5 % and 1.5 %) and seven cabbage genotypes.

The observations recorded on various growth and yield parameters of cabbage and initial and final soil nutrient status during the experiment was analysed statistically and the salient findings of the study are summarized below.

1. There was no significant difference with respect to plant spread among genotypes. However genotype G_1 (NS 43) recorded the maximum plant spread (50.70 cm). The different levels of calcium treatments were on par. Interaction effect was also non-significant with respect to different levels of calcium foliar application. However maximum plant spread was in G_1 C_0 (52.10 cm) and it was minimum in G_8 C_2 (44.60 cm).

2. Genotypes exhibited significant difference with respect to number of non-wrapping leaves. The genotype G_8 recorded the minimum number of non-wrapping leaves (7.70). Calcium foliar application does not show any significant difference. There was no significant interaction effect with different levels of calcium foliar application. However the minimum number of non-wrapping leaves (7.10) was in G_8 C_0.

3. Genotypes showed significant difference with respect to number of wrapping leaves. The minimum number of wrapping leaves (8.60) was in the genotype G_1 (NS 43). Different levels of calcium foliar application had non-significant effect and interaction effect also. The minimum number of wrapping leaves (8.50) was recorded in G_1C_0 interaction.

4. There was significant difference among the genotypes with regard to stalk length. The lowest stalk length was recorded by G_4 (F_1 Border 777) (5.58 cm). Calcium foliar applications had no significant effect on stalk length. There was significant interaction effect on stalk length. The lowest stalk length (5.25 cm) was observed in G_4 C_0.

5. There was significant difference with respect to genotypes for days to 50 % head formation. The genotype G_1 (NS 43) was early to form heads (59.93). Different calcium foliar treatments and interaction effect had non-significant difference. However the interaction G_1 C_0 (control) was early to form heads (59.50).

6. All the genotypes exhibited significant difference for days to 50% head maturity. The genotype G_1 (NS 43) was earliest (75.96) for 50% head maturity. There was no significant difference with different levels of calcium foliar application or interaction effect also. However the interaction G_1 C_2 recorded early head maturity (73.80).

7. Cabbage genotypes raised inside rain shelter showed variation with respect to head compactness. The genotype G_1 (NS 43) formed loose heads in C_2 (1.5 %) treatment, and medium compact heads in other treatments. The genotype G_5 (Green Voyager) formed very compact heads with 0.5% and 1.5% Ca foliar application, whereas heads were compact in control (C_0) treatment. However other genotypes formed very compact heads.

8. The cabbage genotypes raised inside rain shelter showed variation with regard to head shape. Only the genotype G_1 (NS 43) produced round heads and all other genotypes produced conical heads.

9. Genotypes exhibited significant difference with respect to gross head weight. Maximum gross head weight was noticed in G_1 (NS 43) (1136.66

g) and different calcium foliar treatments had non-significant effect. Maximum gross head weight (1365 g) was recorded in G_1 C_2.

10. There was significant difference among the genotypes with respect to net head weight. Maximum net head weight was recorded in the genotype G_1 (NS 43) (787.33 g). The different levels of calcium foliar treatments and interaction effect had no significant difference. The maximum net head weight was recorded in (C_1) (0.5 %) treatment with (677.14 g). The interaction G_1 C_2 recorded the highest net head weight (930 g).

11. Genotypes exhibited non-significant difference with regard to head length. However genotype G_1 (NS 43) had the maximum head length (12.91 cm). Foliar application of different levels of calcium and interaction effect were non-significant.

12. Genotype showed significant variation with respect to head breadth. The genotype G_1 (NS 43) had the highest head breadth (13.40 cm) and different calcium foliar treatments or interaction effect exhibited non-significant difference. However the maximum head breadth (13.90 cm) was recorded in G_1 C_2.

13. There was significant difference among genotypes for core length. The minimum core length was recorded in G_3 (Super Ball 50) (5.71 cm). Different levels of calcium foliar application and interaction effect were non-significant. The interaction G_3 C_0 and G_3 C_2 recorded the minimum core length (5.50 cm).

14. There was significant difference among genotypes with respect to head index. The genotype G_4 (F_1 Border 777) recorded the maximum head index (1.31). Calcium foliar application had non-significant difference. Interaction effect was also non-significant. Head index was maximum (1.37) for G_4 C_0 interaction.

15. Genotypes did not show any significant difference with regard to harvest index. However the maximum harvest index was for the genotype G_8 (Saint) (69.60 %), different levels of calcium foliar application and interaction effect showed non-significant difference. The maximum harvest index (74.61 %) was in G_8 C_1.

16. There was no significant different among the genotypes for total number of marketable heads per plot. However genotype G_4 (F_1 Border 777) recorded the maximum number (11.00) of marketable heads. Calcium foliar application and interaction effect did not show any significant difference. However the interactions G_6 C_1 and G_4 C_1 had maximum number (11.50) of marketable heads per plot.

17. Significant difference was noticed among genotypes for yield per plot. The genotype G_5 (Green Voyager) recorded the maximum yield per plot (6.40 kg). There was no significant difference among different calcium foliar application and interaction effect also, however the interaction G_5 C_2 recorded the maximum yield (6.79 kg).

18. Genotypes exhibited non-significant difference with respect to moisture content irrespective of different levels of calcium foliar sprays. However the genotype G_2 (Green Challenger) recorded maximum moisture content (93.13 %).

19. There was no significant difference among the genotypes for pest and disease incidence. Genotypes G_3 (Super Ball 50), G_4 (F_1 Border 777), G_6 (Mahy 118) and G_8 (Saint) recorded no pest incidence. There was no disease incidence in genotypes G_2 (Green Challenger), G_5 (Green Voyager) and G_6 (Mahy 118).

20. Genotypes showed significant variation with respect to percentage of disease incidence. Genotypes G_1 (NS 43) and G_8 (Saint) recorded the

maximum disease incidence (9.71 %). The different calcium foliar treatments and interaction effect did not show any significant difference. However the maximum disease incidence was recorded for G_2 C_2 with 16.66 per cent.

21. There was no significant effect with respect to genotypes for internal tipburn incidence. Different calcium treatments and interaction effect had non-significant difference. The genotype G_1 (NS 43) recorded a slight incidence of tipburn (4.16 %) and all other genotypes were free from this disorder. Only (C_2) treatment recorded slight incidence of tipburn (1.78 %).

22. Soil samples were collected from all the experimental plots before and after raising the crop. Soil samples were analysed for pH, organic carbon, available P, K, Ca, Mg, Fe and Mn content. There was no significant difference with respect to soil pH, organic carbon, available P, K, Ca, Mg, Fe and Mn content between the plots before and after raising the crop.

23. For analysis of plant samples index leaf (recently matured wrapping leaf and head) were collected from internal tipburn susceptible genotype G_1 (NS 43) and resistant genotype G_5 (Green Voyager). Plant samples were analysed for N, P, K, Ca, Mg, Fe and Mn content both in leaf and head. Here also there was no significant difference among genotypes for N, P, K, Ca, Mg, Fe and Mn content both in leaf and head samples. The foliar application of Ca has increased leaf calcium concentration in both the genotypes. The maximum leaf Ca was recorded in the interaction G_5 C_2 (1.20 %) and it was lowest in G_1 C_2 (1.17 %).

24. The genotype G_5 (Green Voyager) produced very compact heads, with high gross head weight (1005.83 g), yield per plot (6.40 kg), resistance to internal tipburn and high benefit-cost ratio (1.14). Hence this genotype can be recommended for off-season cultivation under rain shelter in the central

plains of Kerala. From the present study it was also found that internal tipburn is a genotype specific disorder which cannot be minimized by Ca foliar application. Earlier studies also indicated that NS 43 is susceptible to this disorder. There are also reports that it is a genetically determined character. Hence more genotypes are to be screened for resistance to internal tipburn. Though Ca foliar application can minimise the incidence of internal tipburn, it increased the yield in genotypes G_1 (NS 43) and G_5 (Green Voyager), when compared to control treatment. Which shows that Ca foliar application has a positive influence on yield.

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APPENDICES

APPENDIX I

Weather data of experimental site (May 2015- September 2015)

Inside rain shelter during off-season

standard week	Inside rain shelter							
	Morning				Afternoon			
	Temp. Max (^{0}C)	Temp. Min (^{0}C)	Relative humidity (%)	Light intensity (Lux)	Temp. Max (^{0}C)	Temp. Min (^{0}C)	Relative humidity (%)	Light intensity (Lux)
23	29.69	28 .73	79.5	27316	30.17	29.08	72.64	24544
24	29.50	28.73	85.75	30956	30.95	29.69	74.75	28383
25	30.25	29.38	73.16	29314	32.78	31.18	56.16	39433
26	28.71	27.97	80.00	15657	29.66	27.78	70.33	19966
27	27.22	26.58	89.16	15255	27.63	27.17	84.66	12227
28	28.26	27.58	86.54	26261	29.44	28.32	75.83	22027
29	29.18	28.49	86.33	18272	31.00	29.70	74.69	29777
30	28.70	27.82	87.66	14222	28.99	28.31	76.83	18816
31	29.60	28.65	89.66	22911	31.36	30.05	80.66	26927
32	29.36	28.22	82.83	26155	30.84	29.44	68.16	29961
33	30.10	29.01	77.16	18816	30.54	29.32	67.33	27622
34	28.85	27.97	83.58	14397	30.39	29.42	70.58	14135
35	28.75	27.91	78.16	21955	29.91	28.87	68.54	25592
36	29.45	28.37	81.66	23588	29.57	28.36	67.66	29733
37	29.88	28.59	74.16	32394	29.89	27.94	66.57	25533
38	29.48	28.60	79.54	25751	30.15	29.06	70.83	24105

APPENDIX II

Weather data of experimental site (May 2015- September 2015)

Outside rain shelter during off-season

Standard week	Outside rain shelter								
	Morning				Afternoon				Rainfall (mm)
	Temp. Max (^0C)	Temp. Min (^0C)	Light intensity (Lux)	Relative humidity (%)	Temp. Max (^0C)	Temp. Min (^0C)	Light intensity (Lux)	Relative humidity (%)	
23	30.00	29.25	75090	91	32.80	31.38	65283	72	6.5
24	28.93	28.47	70717	93	30.74	30.00	69178	65	10
25	29.93	29.16	54850	89	32.80	31.38	86400	70	204.2
26	29.22	28.51	37133	94	30.27	29.69	57416	70	252.5
27	27.62	27.19	35989	94	27.59	27.28	27500	80	284.1
28	29.13	28.48	75883	95	29.75	28.95	70233	85	198.2
29	30.06	29.41	49852	94	31.57	30.46	79583	68	275.7
30	28.70	28.20	35569	95	29.78	28.95	53900	73	306.8
31	30.18	29.13	76166	96	32.03	30.83	73483	84	180.8
32	30.83	29.78	79683	95	31.97	30.79	89583	69	195.8
33	31.94	30.80	68166	94	31.54	30.52	52466	72	125.9
34	29.96	28.95	52050	96	31.11	30.09	50866	76	100.2
35	29.75	29.01	77800	95	31.17	30.06	49500	69	77.5
36	30.46	29.44	74225	95	31.20	30.30	52891	63	68.5
37	31.32	29.96	66033	94	30.89	29.13	72476	72	60.2
38	31.94	30.80	69698	94	31.54	30.52	60545	66	51.2

APPENDIX III

Cost of cultivation of cabbage inside rain shelter (200m^2) during off-season

Items	Cost (Rs.)
A. Labour charges	
1. Nursery preparation (2W)	800
2. Land preparation (4M)	2640
3. Transplanting (1W)	400
4. Irrigation (2M)	1320
5. Fertilizer application (basal dose) (2W)	800
6. Weeding and top dressing (4W)	1600
7. Plant protection chemical application (2M)	1320
8. Harvesting (2W)	800
B. Other inputs	
1. Cost of seed and potting media	500
2. Manures and fertilizers	800
3. Calcium nitrate	118
4. Plant protection chemicals	200
C. Cost of structure	
1. Construction cost	2000
2. Maintenance cost	500
Total cost	**13798**

EVALUATION OF CABBAGE (*Brassica oleracea* L. var. *capitata*) GENOTYPES FOR COMPACTNESS AND INTERNAL TIPBURN RESISTANCE UNDER RAIN SHELTER

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The experiment entitled "Evaluation of cabbage (*Brassica oleracea* L. var. *capitata*) genotypes for head compactness and internal tipburn resistance under rain shelter" was carried out in the department of Olericulture, College of Horticulture, Vellanikkara during the period from May to September 2015. The major objectives of the study were to identify compact genotypes with high yield for rain shelter cultivation, to identify genotypes with internal tip burn resistance, a calcium related physiological disorder and also to study the effect of calcium foliar application on the incidence of internal tip burn. Seven cabbage genotypes were evaluated with three different calcium foliar treatments (0%, 0.5% and 1.5%).

All the cabbage genotypes showed significant difference with respect to qualitative and quantitative characters studied. Number of wrapping leaves, head length, head breadth, net head weight, head index, harvest index and head compactness directly contributed towards yield. The minimum number of wrapping leaves (8.60) was in genotype G_1 (NS 43) and the genotype G_8 (Saint) recorded the minimum number of non-wrapping leaves (7.70). The genotype G_1 (NS 43) recorded maximum plant spread (50.70 cm), head length (12.91cm), head breadth (13.40 cm), net head weight (787.33 g) and gross head weight (1136.66 g). The genotype G_4 (F_1 Border 777) recorded the maximum head index (1.31), but harvest index was maximum for the genotype G_8 (69.60 %). All the genotypes formed very compact heads in all Ca foliar treatments, except G_1 (NS 43) which formed loose heads in C_2 (Ca 1.5 %) treatment, medium compact heads in control (C_0) and C_1 (0.5 %) treatments. All the genotypes produced conical heads except G_1 (NS 43) which produced round heads. The genotype G_5 (Green Voyager) recorded maximum yield of 6.40 kg per plot. Among the seven genotypes, only the genotype G_1 (NS 43) recorded slight tipburn incidence (4.16 %). Genotypes G_3 (Super Ball 50), G_4 (F_1 Border 777), G_6 (Mahy 118) and G_8 (Saint) were free from pest incidence and genotypes G_2 (Green Challenger), G_5 (Green Voyager) and G_6 (Mahy 118) were free from disease incidence.

Effect of different levels of calcium foliar application and the interaction effect were non-significant in most of the characters. However the interaction G_4 C_0 recorded the lowest stalk length (5.25 cm) and interaction G_1 C_2 recorded the highest gross head weight (1365 g). The interaction G_1 C_2 recorded slight incidence of tipburn (1.78 %). There was no pest incidence in the interactions G_8 C_0, G_6 C_1, G_4 C_0 and G_3 C_1. The interactions G_5 C_0, G_2 C_0 and G_6 C_2 registered no disease incidence.

Soil samples were collected from all the experimental plots before and after raising the crop. Soil samples were analysed for pH, organic carbon, available P, K, Ca, Mg, Fe and Mn content. There was no significant difference with respect to soil pH, organic carbon, available P, K, Ca, Mg, Fe and Mn content among the plots before and after raising the crop. Index leaf (recently matured wrapping leaf and head) samples were collected from internal tipburn susceptible genotype G_1 (NS 43) and high yielding, resistant genotype G_5 (Green Voyager). Plant samples were analysed for N, P, K, Ca, Mg, Fe and Mn content both in leaf and head. Here also there was no significant difference among genotypes for N, P, K, Ca, Mg, Fe and Mn content both in leaf and head samples. The foliar application of Ca increased leaf calcium concentration in both the genotypes. Maximum leaf Ca content was recorded in the interaction G_5 C_2 (1.20 %) and it was lowest in G_1 C_2 (1.17 %).

The genotype G_5 (Green Voyager) produced very compact heads, higher net head weight (1005.83 g), yield per plot (6.40 kg) and high benefit-cost ratio (1.52). It was also resistance to internal tipburn. Hence this genotype can be recommended for off-season cultivation under rain shelter in the central plains of Kerala. From the present study it was found that internal tipburn incidence in cabbage is genotype specific and it can be reduced by Ca foliar application. Only the genotype G_1 (NS 43) was susceptible to internal tipburn among the seven genotypes. Hence more number of genotypes are to be screened in further experiments.