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EVALUATION OF POSTHARVEST QUALITY ATTRIBUTES OF CABBAGE AND CAULIFLOWER GROWN IN PLAINS AND HIGHER ALTITUDE

By

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(2009-12-118)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

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(PROCESSING TECHNOLOGY)

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2011

DECLARATION

I hereby declare that the thesis entitled **"Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara

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DECLARATION

Certified that the thesis entitled **"Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude"** is a bonafide record of research work done independently by Mr. K. Elavarasan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned members of the advisory committee of **Mr. K. Elavarasan** (2009- 12- 118), a candidate for the degree of **Master of Science in Horticulture**, with major field in **Processing Technology**, agree that the thesis entitled **"Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude"** may be submitted by his in partial fulfilment of the requirement for the degree

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K. Elavarasan

K. Elavarasan

Dedicated to
My Family,
My Department
and ICAR

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Introduction

1) INTRODUCTION

India is the leading producer of vegetables next to China and occupies prime position in the production of vegetables such as cauliflower, onion and cabbage in the world. Cabbage and cauliflower are introduced vegetable crops of India and the Mediterranean Sea Coast is considered as the centre of origin of these two crops. They were originated from wild form namely *Brassica oleracea var. sylvestris*. Cabbage and cauliflower occupies an important place among cole crops grown in India.

Cabbage is cultivated in an area of 3.1 lakh hectares, with a production of 68.7 lakh tonnes and productivity of 22.1 tonnes per hectare. In the case of cauliflower area, production and productivity are 3.49 lakh hectare, 65.3 lakh tonnes and 18.7 tonnes per hectare respectively (NHB, 2009). Major producing states of cabbage and cauliflower are Bihar, Uttar Pradesh and Orissa. With the development of tropical type, cultivation has spread to the nontraditional areas in South India including Karnataka and Tamil Nadu. The high range regions of Kerala offer ample scope for the cultivation of cole crops, which in turn would reduce the consumer dependence on supply from neighbouring state.

Cabbage (*Brassica oleracea var. capitata* L.) of the family Brassicaceae or Cruciferacea is used as a green leafy vegetable. It is a rich source of minerals like phosphorus, potassium, calcium, sodium and iron. It is grown throughout the country but is more popular in southern states where it is available all the year round. In northern India also, the cabbage availability period has been considerably extended with the development of tropical varieties or hybrids.

Cauliflower (*Brassica oleracea var. botrytis* L.) another popular vegetable among the cole crops, is traditionally grown in areas where the climate is mild. Selections were made from existing lines, to develop varieties with wider adaptability to hot and humid weather conditions. The development of new varieties has resulted in the cultivation of cauliflower in nontraditional areas also.

Cabbage and cauliflower are both thermo sensitive crops. It loses its flavour in dry warm weather condition. Optimum temperatures required for the cultivation of cabbage and cauliflower in plains is 28 to 30°C and in hilly areas are to 23°C.

In recent past the cultivation of cabbage and cauliflower is being extended to the plains of Kerala. As the genotype interact considerably with the environment in which they are grown, identification of genotypes which perform well in the plains will be of immense value to the farmers. There is a growing demand for freshly harvested quality produce. Hence, studies are to be undertaken to identify genotypes with appreciable post harvest quality attributes of produce. Data on the shelf life of the produce is to be generated for handling them properly after harvest to maintain the quality of the produce. Hence the study envisages evaluation of the storage stability of cabbage and cauliflower produced in plains and higher altitudes. As the demand for minimally processed products is gaining importance nowadays the packaging and storage requirement of minimally processed produce has to be standardized.

In this context the present study was under taken with the objectives of:

1) Identification of genotypes with suitable postharvest quality attributes from plains and high altitudes
2) Evaluation of storage stability of cabbage and cauliflower grown in plains and high altitudes
3) Analyzing the shelf life of minimally processed cabbage and cauliflower

Review of literature

2. REVIEW OF LITERATURE

Cabbage and cauliflower occupies an important place among cole crops in India. Cauliflower is grown in an area of about 3.49 lakh hectares throughout the country producing about 65.3 lakh tonnes of annually. Cabbage is grown in all agro climatic zones of India, accounting for approximately an area of 3.1 lakh hectares with production of 68.7 lakh tonnes (NHB, 2009).

Research findings already reported by various workers in the related fields are reviewed under the following headings.

2.1 Comparative performance of genotypes

The performances of genotypes vary with the growing conditions, management practices followed, earliness of the variety, season etc. Sharma and Verma (2000) compared five cultivars of cabbage and found that the hybrid Bahar and Pusa Mukta recorded a yield of 30.79 and 22.27 tonnes/ha respectively compared with the commercially grown variety Golden Acre (14.39 tonnes/ hac).

Cervenski *et al.* (2002) evaluated 12 divergent cabbage genotypes and reported highly significant interactions for head mass, usable portion of head, core length and yield but no interaction were found for head height and diameter, indicating that these two varietal traits have little effect on variability.

In a study conducted by Sharma *et al.* (2003) high and significant differences were observed among eight varieties and 13 hybrids of early Indian cauliflower with respect to days to maturity due to environment for the characters like harvest index, riceyness, curd colour and compactness. The variance due to environment was found highly significant.

Kumar *et al.* (2004) observed positive correlation of curd depth and leaf breadth with net curd weight in late cauliflower and 51 genotypes of mid and late group and they concluded that it was mainly due to indirect effects of gross curd weight and harvest index.

Wurr *et al.* (2004) stated that the phases of juvenility and curd growth were shortened by increased temperature, while in most cases curd induction was increased.

Sharma *et al.* (2005) reported wide range of character variability among the cauliflower accessions and Selection CCS-I (Cauliflower Composite Selection-I) excelled in curd weight, curd color, curd compactness, harvest index and days to marketable maturity.

Sharma *et al.* (2006) studied the genetic variability, in cauliflower and found that the marketable curd yield per plant exhibited a positive correlation with net curd weight, curd size index, number of leaves per plant, curd length, curd breadth and gross plant weight at the genotypic and phenotypic levels.

Thakur (2006) studied the adaptability of 21 genotypes of cauliflower and found that the curd weight, gross weight, curd size index and curd solidity differed significantly among the genotypes. The environment over the years was found to significantly influence the quality of produce.

Yoshiaki *et al.* (2008) reported that cabbage varietal differences were observed in the morphological characters below the base of the head.

Varalakshmi *et al.* (2010) compared the performance of breeding lines of early cauliflower and the analysis of variance has shown significant variation among the genotype of early cauliflower for the characters like total plant weight, leaf number, leaf weight, curd diameter, curd depth, curd size and curd weight.

2.2 Effect of climate on quality attributes of cabbage and cauliflower

The response to global warming trend, organic farming and eco-agriculture practices are currently pursued for water and energy conservation purposes. In western countries such as in Europe and America, efforts are made to develop heat tolerant cabbage and cauliflower. Taiwan played a leading role in breeding heat tolerant varieties of Chinese cabbage and cauliflower (Shyhshyan, 2008).

Dufault and Ward (2003) conducted an experiment to quantify the long term effects of leaf defoliation gradients on yield and quality at various growing stages and the results have shown that early spring cauliflower subjected to damaging hailstorms can severely damage foliage and delay subsequent curd formation.

Ismail and Ann (2004) studied the effects of root cooling and aerial shading on the growth and yield of tropical cauliflower and the results have shown that shading in tropical cauliflower significantly reduced vegetative growth and curd size but enhanced its white colour.

Mckeown *et al.* (2004) reported that yield of cauliflower and cabbage decreased with warmer average temperature, number of days was found to above 30 ° C and with fewer days with precipitation. Higher temperatures probably will increase heat related quality disorders and possibly reduce vitamin content.

Nathoo (2005) assessed the comparative performance of four summer cauliflower varieties and found that summer cultivars exhibited good curd yields during summer transplanting and produced higher yield than the local cultivar.

Chaubey *et al* (2006) tested 23 genotypes of cabbage for fertility levels during two seasons *i.e.* winter spring and spring summer. It was found that in both the seasons higher the fertility, earlier the maturity and vice versa. The spring summer planting resulted in significantly earlier maturity and also numbers of wrapper leaves were always higher as compared to winter spring planting.

Stavang *et al.* (2008) studied the effect of temperature drops on cold resistance of different species. In contrast to a period of low temperature, short diurnal temperature drops did not enhance cold tolerance in white cabbage. Exposure to low temperature of 6°C for six days increased cold tolerance by 2-5°C compared to plants exposed to diurnal temperature drops or control plants. The results are not supporting the hypothesis that diurnal temperature drops improve cold tolerance. However, temperature drops reduce plants size compactness and robustness of plants.

Tanaka *et al.* (2008) compared the relationships between the earliness of head formation and developmental characteristics of cabbage cultivars and found that earliness of head formation was highly correlated with the leaf position at which head formation started.

2.3 Influence of nutrients on quality of cabbage and cauliflower

Rather and Schenk (2005) investigated the effect of nitrogen on curd compactness and the onset of cauliflower bolting at optimum and at limiting nitrogen supply. The results have shown that bolting started four days at optimum nitrogen supply.

Sharma *et al.* (2005) reported the effect of foliar application of micronutrients on shelf life of cabbage. Application of 0.5 per cent borax resulted in compact head during storage for a longer period.

Kanujia *et al* (2006) analysed the effect of micronutrients on growth and yield of cabbage *var.* 'Golden Acre'. The foliar application of Zn @ 100 ppm gave maximum plant height during both the seasons studied. Maximum values for plant spread, number of non-wrapper leaves, head diameter, head weight and head yield were recorded for foliar application of mixture of all nutrients @ 100 ppm.

Singh (2006) analysed the effects of different biofertilizer on cabbage and it showed that usage of biofertilizer enhanced the protein and vitamin C contents along with better shelf life under ambient storage conditions.

Tuvunarivu *et al.* (2006) reported that moderate fertilizer application in cabbage field does not affect the quality of the cabbage. However higher amount of fertilizer may damage its quality.

Atanasova *et al.* (2007) reported that highest yield values for cabbage were obtained with mineral fertilizer application compared to farmyard manure and foliar fertilizer.

Kalalbandi *et al.* (2007) studied the effect of organic and inorganic fertilizers on vegetative growth yield, quality and returns of cabbage var. Pride of India. Vegetative characters *viz.* mean number of leaves, circumference of stem and leaf area was found to be maximum in the treatment involving 25 per cent RDF + 75 per cent FYM and the same treatment gave the highest gross income, percentage increase over gross return and net return over control.

Lashkari *et al.* (2007) conducted a study on cauliflower *cv.* Snowball-16 and the results indicated that leaf area and marketable yield were significantly higher in combined foliar sprays of zinc and iron at 0.5% concentration each.

Marsic and Osvald (2007) reported that application of nitrogen at a rate of 225 kg N ha/1 (for early cultivars) to 300 kg N ha/1 (for midearly cultivars) was optimal for obtaining good yield, superior quality and uniformity.

Organic amendments FYM 200t /ha and phosphorus solubilizing bacteria (PSM) significantly influenced the ascorbic acid, total carotenoid, total carbohydrate and crude fiber content in cabbage head as reported by Upadhyay *et al.* (2007).

The results of the study conducted by Galor *et al.* (2008) revealed that in steamed cauliflower antioxidant content was higher as compared to boiled and microwaved cauliflower.

Khare and Singh (2008) proved from the studies that the application of 75 per cent nitrogen of recommended dosage in combination with azotobacter significantly increased the growth parameters, yield attributes (number of folded leaf, weight and diameter of head) and yield of cabbage.

Sartoride *et al.* (2008) showed that nitrogen levels increased mean weight, yield and nitrogen content of curds. Fertilization increased boron contents in curds, commercial yield and reduced hollow stem disorder.

Dacosta *et al.* (2009) reported that nitrogen and boron did not affect commercial and total yield of inflorescence mass, nitrogen and boron levels of leaves and inflorescences. Hollow stem incidence was reduced by boron application. The highest head yield of cabbage and curd yield of cauliflower was recorded by applying boron@ 2.5 ppm in cabbage and in cauliflower @ 1.0 ppm (Bhat *et al.* 2010).

Rohit *et al.* (2010) conducted a field experiment on cabbage *cv.* 'Pride of India' and showed that in rabi season to study the effect of nitrogen, biofertilizer (azotobacter) and FYM with respect to growth, yield attributing parameters and total yield. All growth and yield attributing characters and yield under study were significantly affected by nitrogen. Days to 50 per cent maturity, number of unfolded leaves, number of days required for head formation, polar diameter, fresh weight of head, dry weight of head and yield were found to be maximum with application of nitrogen @ 150 kg/ha.

2.4 Physiological disorders

Adamicki (2003) reported that low concentration of CO_2 and O_2 highly decreased the range of physiological damages and also improved quality and marketable value of cauliflower.

Everaarts and Deputter (2003) studied the effect of application of boron on variation in the growth rate of the crop and effects on the occurrence and degree of hollow stem. There was no causal relation between the boron content of the stem at harvest and the occurrence and the length of the cavities. However, a positive relation between the average growth rate of the stem and the percentage of affected plants was observed.

2.5 Studies on postharvest technology

Eliot *et al.* (1999) investigated the feasibility of processing cauliflower by ohmic heating. Low temperature precooking increased the firmness of cauliflower subjected to ohmic heating. The ohmic heating combined with low temperature precooking in saline solutions offers a viable solution to high temperature/ short time sterilization of cauliflower florets.

Xu *et al.* (2007) studied the effect of microwave sterilization during the drying process and effects of the pressure, thickness of material being dried, and the input microwave power on indices such as drying time and the microorganism number. Compared with the method of ordinary freeze drying, microwave freeze drying (MFD) can greatly reduce the drying time and has a notable sterilization effect.

Galor *et al.* (2008) reported that cooking may affect antioxidant content due to antioxidant release, destruction or creation of redox active metabolites in cabbage and cauliflower.

Mudgal and Pandey (2008) studied the effect of method of drying on quality of dried cauliflower. Cauliflower was blanched for two minutes in 5 per cent salt solution, 0.5 per cent citric acid solution and 0.75 per cent potassium meta bisulphate solution before drying. Open sun drying, solar drying and mechanical drying was carried out in three different temperatures of 60, 70 and 80°C. Those dried in mechanical driers were more acceptable as compared to sun dried and solar dried products. The rehydration ratio and coefficient of rehydration were the highest in cauliflower blanched with preservative solution at all the drying temperature. The rehydrated product could be well utilized for substituting the fresh product in off season.

Scalzo *et al.* (2008) analysed the violet cauliflower and red cabbage for their anthocyanin profiles before and after thermal treatments. All thermal treatments, except microwave heating, drastically reduced total anthocyanin content in cauliflower

Sikora *et al.* (2008) analysed the antioxidising agents, vitamin C, carotenoids and polyphenols in cauliflower and cabbage. Cauliflower was found to contain the smallest amount of these compounds compared to kale. The aquathermal processes were found to reduce these compounds further due to escape of vitamin C and polyphenols into the water environment.

Chiewchan and Morakotjinda (2009) analysed the heat resistance of *Salmonella anatum* inoculated onto the surface of cabbage slices as affected by acetic acid pretreatment (0.5-1.5% v/v) and hot air drying at 50-60°C. The heat resistance of *Salmonella* on the cabbage surface treated with acetic acid decreased considerably compared with untreated cabbage. Moreover, the cabbage treated with higher acetic acid concentration resulted in a higher degree of acid injury and hence increased the susceptibility to heat during drying. The results revealed that acetic acid pretreatment may be used as an additional processing step to increase the safety margin of dried cabbage products.

2.6 Studies on storage quality

Jayaraman *et al.* (1990) studied the effect of soaking the blanched pieces of cauliflower in solution of common salt and sucrose alone or in combination at varying concentrations. They found that the optimum treatment was soaking in 3% salt and 6% sucrose for 12- 16 hours at 4°C for dehydrated cauliflower. It markedly reduced shrinkage and improved rehydration without affecting palatability and also shelf life of the product from 3 to 12 months at ambient temperature.

Madhavi and Ghosh (1998) observed that fresh cauliflower is delicate and ordinarily not stored for long period due its poor shelf life, but good compact head can be kept in cold storage for 3-4 weeks at 0°C with 85-90% relative humidity.

Buike and Alsina (2003) reported that the lack of calcium in cabbage reduced its storage potential. Dressing with calcium nitrate ($Ca(NO_3)_2$) or ammonium nitrate (NH_4NO_3), once per vegetative period resulted in increased yield in cabbage. However, Rennie *et al.* (2003) reported that optimum temperature for safe storage of cauliflower is 0°C at 95-98% relative humidity.

Gajewski (2004) examined that the polyphenolic acid content in cauliflower as affected by growing period, cultivar and storage conditions. Controlled atmosphere conditions inhibited the changes in polyphenolic acids concentration in stored curds to certain extend.

Cao *et al.* (2007) studied the effect of high maltose sugar as an osmotic agent in preparation of dehydrated cabbage. They reported that high maltose syrup had more efficient dehydration and osmosis capability than fructose. Osmotic pretreatment with high maltose syrup was helpful in reducing energy consumption and for enhancement of the drying rate.

Catalano *et al.* (2007) studied the effect of stage of harvest and different modified atmosphere packaging on colour, total polyphenol content and activities of polyphenol oxidase in Chinese cabbage. Samples harvested at different ripening steps showed appreciable differences in all parameters tested on the production day and chilled storage. However samples kept under modified atmosphere condition showed differences in polyphenol oxidase activity and browning during chilled storage.

Kadam *et al.* (2008) reported the impact of blanching time, pretreatment, storage and packaging on the physio chemical properties of solar dehydrated cauliflower. The treatment blanching for nine minutes followed by dipping in one per cent KMS solution and then packing in laminated aluminium foil showed better results as compared to other treatments.

Kmiecik *et al.* (2008) studied the effect of low storage temperature on retention of chlorophyll in cauliflower and reported that low temperature storage resulted in higher content of chlorophyll. However Taniwakia *et al.* (2009) reported that low temperature storage did not effectively retain the texture and quality of the cabbage.

Dhall *et al.* (2010) reported that the use of cling wrap films should be avoided for storage of cauliflower as this leads to accumulation of excessive moisture resulting in spoilage. Cauliflower curds individually packed in high density polyethylene bags (20μm) with perforation (6 holes/bag) could be stored up to 21 days at 0 ± 1°C and 90–95% RH with maximum retention of white colour of curd, minimum spoilage, weight and firmness loss and good sensory quality attributes.

Penas *et al.* (2010) evaluated the impact of high hydrostatic pressure (HHP) on the microbial quality of sauerkraut during refrigerated storage for one to three months. They reported that HHP could be considered as an efficient method to improve the microbial quality and shelf life of sauerkraut.

2.7 Biochemical characteristics studies:

Ramaswamy and Ranganna (1989) studied the influence of blanching time and SO_2 treatment on the residual peroxidase activity and its implication on the sensory quality of frozen cauliflowers. They reported that residual peroxidase activity, which ranged from 1 to 5.5 per cent in the blanched samples were to below one per cent in the SO_2 treated samples and SO_2 content of 50 ppm found in these stored samples disappeared after three minute cooking in boiling water.

Singh (2004) evaluated the variability of some important antioxidants and minerals between and within the crucifer accessions in edible portions of plants. The result have been shown that total carbohydrate content ranged between 2.54 to 4.03 g/100g whereas, protein content ranged from 0.41 to 3.57 g/100 g of fresh weight. Mean fiber content ranged from 0.60 to 3.62 g/100g, vitamin C content ranged from 22.16 to 82.14 mg/100 g and ß carotene content ranged from 1.56 to 9.09 mg/100 g on fresh weight basis.

Abusalem *et al.* (2007) studied the effect of blanching processes on the content of ascorbic acid, total carotenoids (Provitamin A) and iron content of cabbage. The results have shown that the blanching techniques significantly decreased ascorbic acid, carotenoids and iron content of the cabbage.

Hsiaopei *et al.* (2007) analysed the indole glucosinolates content including glucobrassicin, indole-3-carbinol (13C), and indolo[3,2-b] carbozole (ICZ) of locally cultivated cabbage and cauliflower in Taiwan. The results indicated that small Chinese cabbage and cabbage sprouts had the highest contents of indole glucosinolates.

Singh *et al.* (2007) studied the sinigrin (2-propenyl glucosinolate) content and myrosinase (thioglucosidase) activity in edible portions of broccoli, white cabbage, Chinese cabbage, cauliflower, Brussels sprouts, red cabbage and Savoy cabbage.

Broccoli (3.23 mg/100 g) recorded the highest sinigrin content. Brussels sprouts (0.343 units/mg protein), Savoy cabbage (0.036 units/mg protein) and Chinese cabbage (0.041 units/mg protein) recorded the lowest sinigrin and myrosinase content.

Koksal and Gulcin (2008) analysed the antioxidant activity of water and ethanol extracts of cauliflower to evaluate their potential value as a natural ingredient for foods or cosmetic application. In this study, antioxidant activity was measured by 2,2'-azino-bis, 1,1-diphenyl-2-picryl-hydrazyl free radical (DPPH), N,N-dimethyl-p-phenylenediamine dihydrochloride (DMPD) and superoxide anion radical scavenging.

Kusznierewicz *et al.* (2008) studied the overall antioxidant properties as a consequence of fermentation of cabbage and/or heat treatment of cabbage juices and extracts. Fermentation processes as well as heat treatment was found to increase the initial values of antioxidant activity. A decrease in the antioxidant potential of sauerkraut juice was found for short heat treatments.

Sultana *et al.* (2008) examined the effects of different cooking methods (boiling, frying and microwave cooking) on the antioxidant activity of cabbage and cauliflower. It was assessed by measuring the total phenolic contents (TPC), reducing power and percentage inhibition in linoleic acid system. The results showed that all the cooking methods affected the antioxidant properties of the vegetables. However microwave treatment exhibited most deleterious effects when compared with that of other treatments.

Volden *et al.* (2008) analysed the various thermal processing treatments (blanching, boiling and steaming) of red cabbage by measuring level of glucosinolates (GLS), total phenols (TP), total monomeric anthocyanins (TMA), L-ascorbic acid (L-AA), soluble sugars and the antioxidant potential. This was analysed by the ferric reducing ability power (FRAP) and oxygen radical absorbance capacity

(ORAC) assays. There were significant losses of all this biochemical components due to thermal processing.

Xiaofeng *et al.* (2008) studied the content of proline, soluble protein, malonaldehyde, superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) activities of Chinese cabbage at different developmental stages, under high temperature conditions of the summer season. The results suggested that the variations of proline, soluble protein, malonaldehyde contents and enzyme activities are probably related to the biochemical mechanism of heat tolerance in Chinese cabbage.

Cebert *et al.* (2009) reported that cabbage had the lowest protein content compared to all the leafy vegetable like canola, collard, greens and kale.

Ciska *et al.* (2009) investigated the effect of the boiling process on the content of ascorbigen, indole-3-carbinol, indole-3-acetonitrile, and 3,3'-diindolylmethane in fermented cabbage. The results have shown that there was decrease in the total content of the compounds analysed. The changes were mainly caused by leaching of ascorbigen predominating in cabbage into cooking water and by its thermal hydrolysis.

Hounsomea *et al.* (2009) studied the changes in antioxidant compounds in white cabbage during six months of commercial storage. Changes in antioxidant compounds in cabbage during long-term storage reflect on several ongoing processes such as postharvest senescence, biennial cycle and response to fungal infection.

Jagdish *et al.* (2009) studied the total phenol content and free radical scavenging activity of methanolic extracts from different brassica vegetables. The total phenol in red cabbage was found to range from 18.7 to 101.30 mg gallic acid equivalent /100 g fresh weight of cabbage. The antioxidant activity ranged from 13.1 in red cabbage to 2.8 μ moles trolox equivalents per gram in white cabbage fresh sample. The linear regression analysis of data showed a significant positive correlation between total phenolic contents and free radical scavenging capacity.

Volden *et al.* (2009) analysed the effect of blanching and one year freezer storage on one purple, two white and two green varieties of cauliflower to asses the effects on several health related phytochemical attributes. The result revealed that blanching of cauliflower prior to freezing reduced total aliphatic, indole glucosinolates, L- ascorbic acid, total phenols and anthocyanin.

Martinez *et al.* (2010) conducted studies to determine and compare the values of some physicochemical parameters (Moisture, soluble solids, titratable acidity, pH, protein, ash, vitamin C, total phenolics, chlorogenic acid, caffeic acid, p-coumaric acid, quercitin and chlorophyll) in different edible portions of white cabbages. The mean values of parameters measured in leaves were higher than those measured in stems except for moisture content.

2.8 Minimally processed product

Kaur and Kapoor (2001) studied the effect of different dip treatments and storage period on the antioxidant activity and biochemical quality of minimal processed Indian cabbage. The results have shown that incorporation of ascorbic acid and citric acid in the dip water improved the overall appearance and retained maximum antioxidant activity, ascorbic acid and total carotenoids. Based on the overall quality and appearance score, "Golden Acre" was found suitable for minimal processing with a shelf life of nine days.

Opatova *et al.* (2003) evaluated the efficiency of different chemicals and physical decontamination methods on cut cabbage and carrot. The results have shown that retention of ascorbic acid varied from 50 to 70% and the losses increased with storage duration. No significant sensorial changes were detected after chemical treatments, while physical treatments led to changes in appearance and texture.

Ibrahim *et al.* (2004) conducted a study to determine the effect of dipping of minimally processed shredded cabbage in anti browning agents on the colour changes and sensory properties of minimally processed shredded cabbage during storage at low temperature 5 ± 1^{O}C, 90 – 95 % RH. Treatment with 0.1% sodium meta bisulphate gave better storage quality followed by 0.1% acetic acid meanwhile combination of 0.5% L- cysteine + 0.1% citric acid and 0.1% ascorbic acid solution were not effective in maintaining the storage quality of minimally processed shredded cabbage.

Dantasi *et al.* (2005) investigated the effect of manipulated package characteristics on the consumer intention to purchase minimally processed cabbage. The results have shown that production type, colour and price had a significant effect on the consumer's intention to purchase minimally processed cabbage.

Khattak *et al.* (2005) studied the influence of different levels of irradiation of minimally processed cabbage on microbial safety, texture and sensory quality. Minimally processed, polythene packed and irradiated cabbage was stored at refrigerator temperature (5°C) for two weeks. No coliform bacteria or fungi were detected at radiation doses greater than 2 KGy in cabbage sample

Makino *et al.* (2006) examined whether dissolving a nonpolar gas in cell sap can prolong the shelf life of horticultural products. Specifically the effect of xeon, which increases the viscosity of aqueous solutions on cabbage that has been shredded to promote access of the gas to the cell sap was studied. The study suggested that storage in xeon can be used to maintain product quality.

Hu *et al.* (2007) studied the respiration rates of fresh cut cabbage in 25 and 30 μm thick oriented polypropylene films (OPP) at 5 and 20°C. Vertical cutting (VC), parallel cutting (PC) and thickness of film did not affect respiration at 5°C. Respiration rates were much higher in VC treatments than in PC treatments at 20°C regardless film thickness. Better quality could be obtained with low temperature (5°C) storage regardless of thickness of film or cutting mode.

Hu *et al.* (2007) reported the effects of perforated film package (PFP) on the gas concentrations and respiration rates of fresh cut cabbage with different initial O_2 concentrations and temperature. The results suggest that better quality retention of fresh cut cabbage could be achieved with perforated film package (PFP) with initial O_2 level of 5-8% at 5°C.

Jongnam *et al.* (2007) investigated the effects of high concentration of CO_2 treatment on the blackening and quality changes of cut cabbage. The polyphenol oxidase activity was lower in the cut cabbages treated with CO_2 than in the control. Total phenolics concentration decreased slowly in the cut cabbages as PPO activity was inhibited by CO_2. Fastened blackening occurred in the control during storage and there was positive relationship between blackening index and PPO activity.

Wenzhong *et al.* (2007) studied the effect of perforated film packages (PFP) with different oxygen partial pressure and a barrier package (BP) at 21kpa of O_2 on the quality of fresh cut cabbage at 5 and 20°c. The result indicated that fresh cut cabbages had better colour retention and quality in PFP. Analysis of microbial growth also showed that the total count on fresh cut cabbage were inhibited effectively using PFP.

Randazzo *et al.* (2008) analysed the dynamics of microbial population in minimally processed Chinese cabbage samples subjected to chlorine, ascorbic acid and lactic acid washing procedures. The results have shown that washing treatment with ascorbic acid/chlorine solution and the modified atmosphere packaging can guarantee the shelf life of minimally processed Chinese cabbage.

Simon *et al.* (2008) evaluated the effect of atmosphere modification, generated using three different packaging films (Perforated PVC, Non-perforated

PVC and Polypropylene films) on the quality of minimally processed cauliflower stored at four or eight degree centigrade for up to 20 days. The result showed that the different packaging conditions and storage temperature influenced yellowing and weight losses.

Buesa *et al.* (2009) reported that modified atmosphere packaging with microperforated films is useful for fresh cut cauliflower and facilitates gas interchange through the package.

Glahan (2009) studied the effect of Co_2 and O_2 during the storage of fresh cut red cabbage in different packaging material. The fresh cut red cabbage was packed under polypropylene bag showed the longest storage life of 18 days, while those stored in laminated bag had the shortest storage life of eight days. There was significant influence on CO_2 and O_2 content in different packaging materials.

Koide *et al.* (2009) compared the disinfection efficacy of slightly acidic electrolyzed water with that of sodium hypochlorite solution in fresh cut cabbage. Analysis of the results showed that the disinfectant efficacy of electrolyzed water was equivalent to or higher than that of NaCl solution. Results also indicated that electrolyzed water under shaded and sealed conditions could keep its available chlorine during storage.

Madalena *et al.* (2009) reported that the stability of fresh cut cabbage was higher at the temperature of 5°C compared to that stored in the refrigerated condition. The active modified atmosphere was not effective in extending the shelf life of fresh cut cabbage compared to other treatments. Low density polyethylene packaging was more suitable for fresh cut cabbage storage. PVC wrapping also presented satisfactory effects.

Marta *et al.* (2009) studied the quality of minimally processed Chinese cabbage treated with different levels of calcium chloride ($CaCl_2$), ascorbic acid (vitamin C) and ethylene diamine tetracetic acid (EDTA) and kept under refrigeration, for different durations. All treatments significantly influenced the physicochemical characteristics affecting the general appearance and causing darkening. No *Salmonella* was detected in the treatments. The work concluded that Chinese cabbage minimally processed under the adopted experimental conditions would be suitable for consumption only up to the fourth day of storage.

Olarte *et al.* (2009) analysed the impact of light on minimally processed cauliflower packaged in four different film types (Poly vinyl chloride and three P-Plus). The effect on the sensory quality due to stored at 4°C in darkness and under light was evaluated. For cauliflower in conditions of darkness, P-Plus 120 film proved the most suitable for preserving its sensory qualities, while under conditions of light, this film did not prove suitable due to its low permeability.

Rai *et al.* (2009) reported that shredded cabbage washed with 0.5% citric acid content and stored in modified atmospheric packaging recorded drastic reduction in chlorophyll, β carotene content while the ascorbic acid content was affected marginally. The non washed samples of shredded cabbage retained more pigments and antioxidant.

Sothornvit (2010) reported that the overall acceptance of fresh cut basil from ozonated washing had a higher score than from chlorinated washing. The potential of ozonated washing method to substitute traditional chlorinated washing to prolong the shelf life of fresh cut vegetable was obvious from this study

2.9 Packaging studies

Makino (2001) enclosed the shredded cabbage in a package of a polymeric film according to the optimized packaging conditions. The oxygen and CO_2 concentrations in the package were controlled at effective levels for the storage of shredded cabbage.

Sharma and Ghuman (2003) studied the effect of packaging and transportation of cabbage in jute bags and baskets in Punjab state. This practice resulted in loss of cabbage in postharvest handling period and commodity suffered loss of quality but if CFB boxes were used, extension in the postharvest shelf life of cabbage was possible and hence could be used for long distance market.

Elisabete *et al.* (2004) reported that the minimally processed cabbage was in good sensorial conditions upto 20 days of storage at 1°C and 5°C in the packaging materials of high O_2 permeability. After five days of storage at 12°C the fresh-cut cabbage presented evident signs of deterioration, as dark spots, slime and off odour.

Ibrahim and Saari (2005) studied the effect of using different types of polymeric films [polypropylene (PP), low density polyethylene (LDPE), high density polyethylene (HDPE) and PVC cling wrap (control)] of varying permeabilities to gas and water vapour and also with and without the application of vacuum packaging on the physical characteristics and sensory aspects of the minimally processed (MP) shredded cabbage during storage at 5±1°C and 90-95% RH. The results have shown that polypropylene could extend the shelf life of the MP shredded cabbage almost upto three weeks with minimum colour change, reduction in weight loss and deterioration in sensory properties and marginally low changes in other parameters.

Madalena *et al.* (2005) evaluated the changes in the minimally processed cabbage when stored in different packages and temperatures. They reported that polyvinyl chloride packages presented lower vitamin C loss during 15 days of storage at all temperatures.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, during 2009- 2011. The materials used and the methods followed in the present study are given under the following headings.

3.1 Evaluation of genotypes for quality attributes

3.2 Evaluation of storage qualities

3.3 Data on weather parameters

3.1 Evaluation of genotypes for quality attributes

Cabbage and cauliflower was simultaneously raised in the plains (ARS Mannuthy) and hills (Orange and Vegetable farm, Nelliyampathy) for evaluation of postharvest quality attributes. Planting was done in RBD with five replications. Random samples of five numbers from each plot were harvested for analyzing the quality.

The genotypes evaluated were:

Cabbage: NS183, NS160, NS 35 and Tropical Sun Plus

Cauliflower: NS 60 N, NS133, Pusa Meghna and Basant

3.1.1 Physical characteristics:

Physical characteristic evaluated were:

3.1.1.1 Days to maturity
3.1.1.2 Curd/ head yield
3.1.1.3 Curd/ head weight
3.1.1.4 Curd/ head height
3.1.1.5 Curd/ head solidity

3.1.1.6 Cooking quality by recording sensory attributes

3.1.1.7 Physiological disorders

3.1.1.1 Days to maturity

Days to maturity was measured as days from sowing to physiological mature of cauliflower and cabbage. Cabbage is ready for harvest at 90- 120 days after planting. Maturity is indicated by compactness and maximum size of the head.

Cauliflower is ready for harvest at 90- 120 days after planting. Depending upon the variety the curds should be harvested promptly when they are of full size but still compact, whitish and smooth. Loose floral parts are signs of over maturity. These are the measurable keys to judge harvest maturity of cauliflower and cabbage.

3.1.1.2 Curd/ head yield

Field consisted of 40 plots, each plot of area 16 square meters, so yield was calculated in terms of yield per 16 square meters. Yield of cabbage and cauliflower was expressed as kilogram per unit area.

3.1.1.3 Curd/ head weight

Cauliflower curd and cabbage head weight were measured using a weighing balance and expressed in grams per curd or head.

3.1.1.4 Curd/ head height

Cauliflower curd and cabbage head height were measured using a scale and expressed in centimeters. In both cabbage and cauliflower the height of longitudinal cut section was measured as curd/ head height.

3.1.1.5 Curd/ head solidity

Cauliflower curd and cabbage head solidity was measured by visual observation.

3.1.1.6 Cooking quality by recording sensory attributes

Cooking quality of cabbage and cauliflower was evaluated by sensory evaluation method using nine point hedonic scale.

3.1.1.7 Physiological disorders

Decay or physiological disorders of cabbage and cauliflower was determined by visual observation.

3.1.2 Biochemical characters:

The biochemical characters of cabbage and cauliflowers constituents analysed were

3.1.2.1 Moisture content
3.1.2.2 Acidity
3.1.2.3 Ascorbic acid
3.1.2.4 Protein
3.1.2.5 Phosphorus
3.1.2.6 Calcium
3.1.2.7 Potassium

3.1.2.1 Moisture content

The moisture content of cabbage and cauliflower was determined using a digital moisture meter model manufactured by Ohaus (Model MB 45).

3.1.2.2 Acidity

Acidity of cabbage and cauliflower was determined by titration with standard sodium hydroxide (0.1N) and expressed as per cent of citric acid as per Ranganna (1997).

One gram of the sample was weighed accurately into a thimble and placed in 250ml conical flask. 100ml water was added and boiled for 15 minutes on the gas burner. Extract was cooled under tap water and made up to 250ml in a volumetric flask. It was mixed well and filtered through filter paper and 30ml supernatant was collected in 250ml volumetric flask. Few drops of phenolphthalein indicator was added and titrated with 0.1N NaoH. End point of titration was pink colour of solution in the beaker. Acidity was expressed in percentage.

3.1.2.3 Ascorbic acid

Ascorbic acid content of cabbage and cauliflower were estimated by 2,6 dichlorophenol indophenol dye method.

3.1.2.4 Protein

The protein content of cabbage and cauliflower was determined by Lowry's method.

The samples (0.5g) were ground well in a mortar and pestle with 5- 10ml of phosphate buffer. It was centrifuged and supernatant used for protein estimation was pipetted out into a series of test tubes. Sample extract (0.1ml) was pipetted out in other test tubes. Tubes with one ml water served as blank.

To each test tube including blank, Reagent C (5ml) was added. It was mixed well and allowed to stand for 10 minutes. To all test tubes Reagent D (0.5ml) was added, mixed well and incubated at room temperature in the dark for 30 minutes till blue colour was developed. Optical density values were recorded in a spectrophotometer at 660 nm. A standard graph was drawn and the amount of protein in the sample was calculated.

3.1.2.5 Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1958), which give yellow colour with nitric acid vanadate molybdate reagent.

To 5ml of predigested aliquot, 5ml nitric acid vanadate molybdate reagent was added and made up to 5ml with distilled water. After 10 minutes the optical density was read at 420nm. Standard graph was prepared by using serial dilution of standard phosphorous solution. Phosphorus content was expressed as mg per 100g.

3.1.2.6 Calcium

Calcium content was estimated by Atomic Absorption Spectrophotometer from digested sample of cabbage and cauliflower.

3.1.2.7 Potassium

The potassium content was estimated using flame photometer as suggested by Jackson (1958). 5ml of digested sample was made up to 50ml and read directly in flame photometer and potassium content was expressed in mg per 100g.

3.2 Evaluation of storage qualities

The genotype performing well in terms of yield and quality both in plains and higher altitude was used for studying the shelf life.

3.2.1 Whole produce

Cabbage and cauliflower immediately after harvest were packaged in the following packaging materials and stored for a period of two weeks under different temperature regimes like 0-1° C, 4- 6°C and ambient temperature.

3.2.1.1 Treatment

T_1- Cling film packaging

T_0- Control

The experiment was laid out in completely randomized design with two replications of whole produce.

3.2.1.2 Observations

The observations on physical, biochemical and shelf life characters were recorded at weekly intervals. The biochemical characters were recorded at the beginning and at the end of the storage period.

3.2.1.2.1 Physiological loss in weight

Weight of fresh cabbage and cauliflower was recorded before storage and subsequent reduction in weight was recorded at weekly intervals as long as the cabbage and cauliflower remained in a marketable stage. Cabbage and cauliflower was declared unsuitable when more than 25 per cent of sample exhibited symptoms of decay, mould growth, shriveling or shrinking.

$$PLW\% = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.2.1.2.2 Colour change

Colour of cabbage and cauliflower during storage was recorded by visual observation.

3.2.1.2.3 Decay/ Disorder

Decay of cabbage and cauliflower was recorded by visual observation.

3.2.1.2.4 Cooking quality

Cooking quality of cabbage and cauliflower was recorded by sensory evaluation of cooked samples.

3.2.1.2.5 Ascorbic acid content

Same as mentioned in 3.1.2.3.

3.2.1.2.6 Shelf life

Shelf life of cabbage and cauliflower was recorded by visual observation.

3.2.2 Minimally processed produce

Cabbage after washing was shredded and the cauliflower was separated to individual florets. The florets and shredded pieces were immersed in two per cent warm salt water for 10 minutes and air dried. Both were packaged in the following packaging materials and stored under different temperature regimes for a period of two weeks.

3.2.2.1 Treatments

T1 - High density polyethylene

T2 - Semi rigid metallised aluminum tray over wrapped with cling film

T3 - Polypropylene

T4 – Control (without packaging)

The experiment was laid out in a completely randomized design with two replications of 100g each.

3.2.2.2 Observations

The observation on physical and shelf life characters were recorded at weekly intervals.

3.2.2.2.1 Physiological loss in weight

Same as mentioned in 3.2.1.2.1

3.2.2.2.2 Colour change

Same as mentioned in 3.2.1.2.2

3.2.2.2.3 Decay/ Disorder

Same as mentioned in 3.2.1.2.3

3.2.2.2.4 Cooking quality

Same as mentioned in 3.2.1.2.4

3.2.2.2.5 Ascorbic acid content

Same as mentioned in 3.1.2.3

3.2.2.2.6 Shelf life

Same as mentioned in 3.2.1.2.6

3.3 Weather parameters

Weather parameter of area of research was recorded from the meteorological weather data recording notebook maintained at plains (College of Horticulture, Vellanikkara) and hills (Orange and Vegetable farm, Nelliyampathy).

Results

4. RESULTS

The results of the study on "Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude" are presented under the following major headings in this chapter.

4.1 Evaluation of genotypes for quality attributes

The postharvest quality attributes of cabbage and cauliflower genotypes were evaluated in a trial conducted at ARS Mannuthy (Plate 1a)in plains and Orange and Vegetable farm, Nelliyampathy in high altitude region (Plate 1b). Four genotypes each in cabbage (NS 160, NS 35, NS 183 and Tropical Sun Plus) and cauliflower (NS 60 N, NS133, Pusa Meghna and Basant) were evaluated in hills and plains (Plate 2& 3).

4.1.1 Physical characters

4.1.1.1 Cabbage

4.1.1.1.1 Days to maturity

The stages in the development of cabbage and cauliflower were studied (Plate 4). Days to maturity was measured as days from sowing to physiological maturity in the case of cauliflower and cabbage. Maturity was indicated in cabbage by compactness as well as maximum size of the head. In cabbage, genotype NS 183 matured early (100.80 days) in hilly region than in plains (133.84 days). This particular genotype was an early maturing type compared to all the other genotypes raised in hills. In plains no significant difference was noticed between the genotypes in days to maturity (Table 1). Cabbage heads took more days to reach harvest maturity in plains as compared to hills.

4.1.1.1.2 Head yield

The cabbage genotype NS 183 recorded highest head yield (29.3 Kg/16 m^2 plot) among all genotypes grown in hilly region. In plains, Tropical Sun Plus

Table 1. Comparison of days to maturity (days) of cabbage genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 160	103.76 (10.2) [c]	133.20 (11.56) [a]	246.47**
2	NS 35	102.84 (10.1) [b]	133.20 (11.56) [a]	274.11**
3	NS 183	100.80 (10.0) [a]	133.84 (11.59) [b]	298.31**
4	Tropical Sun Plus	103.88 (10.2) [d]	133.86 (11.59) [b]	291.60**

Table 2. Comparison of head yield (Kg/16 m^2 plot) of cabbage genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 160	23.2 (4.86) [c]	1.270 (1.33) [d]	41.968**
2	NS 35	22.6 (4.80) [d]	1.380 (1.37) [b]	29.455**
3	NS 183	29.3 (5.45) [a]	1.340 (1.35) [c]	46.782**
4	Tropical Sun Plus	24.7 (5.02) [b]	22.06 (4.70) [a]	1.9184**

Figures in parentheses are SQRT transformed values

** Significant at 1% level

Table 3. Comparison of head weight (g) of cabbage genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 160	610.4 (24.7) ^{d}	80.20 (8.90) ^{b}	15.845**
2	NS 35	645.6 (24.41) ^{b}	51.80 (7.23) ^{c}	18.410**
3	NS 183	816.8 (28.51) ^{a}	46.96 (6.80) ^{d}	28.802**
4	Tropical Sun Plus	638.8 (25.20) ^{c}	729.6 (27.02) ^{a}	2.1167**

Table 4. Comparison of head height (cm) of cabbage genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 160	13.23 (3.7) ^{b}	7.97 (2.91) ^{d}	21.155**
2	NS 35	12.99 (3.6) ^{c}	8.23 (2.95) ^{c}	14.031**
3	NS 183	14.96 (3.9) ^{a}	8.51 (3.00) ^{b}	21.458**
4	Tropical Sun Plus	12.23 (3.5) ^{d}	11.1 (3.40) ^{a}	3.0341**

Figures in parentheses are SQRT transformed values

** Significant at 1% level

(TSP) recorded highest yield (22.06 Kg/16 m^2 plot) as compared to other genotypes. Head yield of other genotypes, were very low when raised in the plains (Table 2).

4.1.1.1.3 Head weight

The recorded head weight (816.8g) of cabbage genotype NS 183 was highest among all genotypes grown in hilly region. TSP recorded highest head weight (729.6g) which was significantly higher than all other genotypes raised in plains (Table 3).

4.1.1.1.4 Head height

Cabbage genotype NS 183 registered highest value for head height (14.96 cm) in hilly region. TSP recorded highest head height (11.11 cm) compared to all the other genotypes raised in plains. Variation in head height observed in the same genotype when raised in hills and plains was significant (Table 4).

4.1.1.1.5 Head solidity

No significant difference was noticed in terms of head solidity for both the regions.

4.1.1.1.6 Sensory quality attributes of cabbage

4.1.1.1.6.1 Genotype Tropical Sun Plus

Cooking quality of cabbage was evaluated by organoleptic method before and after one week of storage. The mean scores obtained for various quality attributes like colour, flavour, texture, taste and overall acceptability of cabbage before storage and after one week storage are presented in Table 5. Score obtained for different quality attributes of TSP was found to be statistically significant between the regions.

The highest mean score for colour (4.66), taste (4.5), texture (4.3), flavour (4.6) and overall acceptability (4.75) was recorded for cabbage grown in

Plate 1. Over view of farm

1 a. Agricultural Research Station, Mannuthy

1 b. Orange and Vegetable farm, Nelliyampathy

Plate 2. Cabbage genotypes evaluated

NS 35

Tropical Sun Plus

NS 183

NS 160

Plate 3. Cauliflower genotypes evaluated

NS 133

NS 60N

Pusa Meghna

Basant

Plate 4. Developmental stages of cabbage

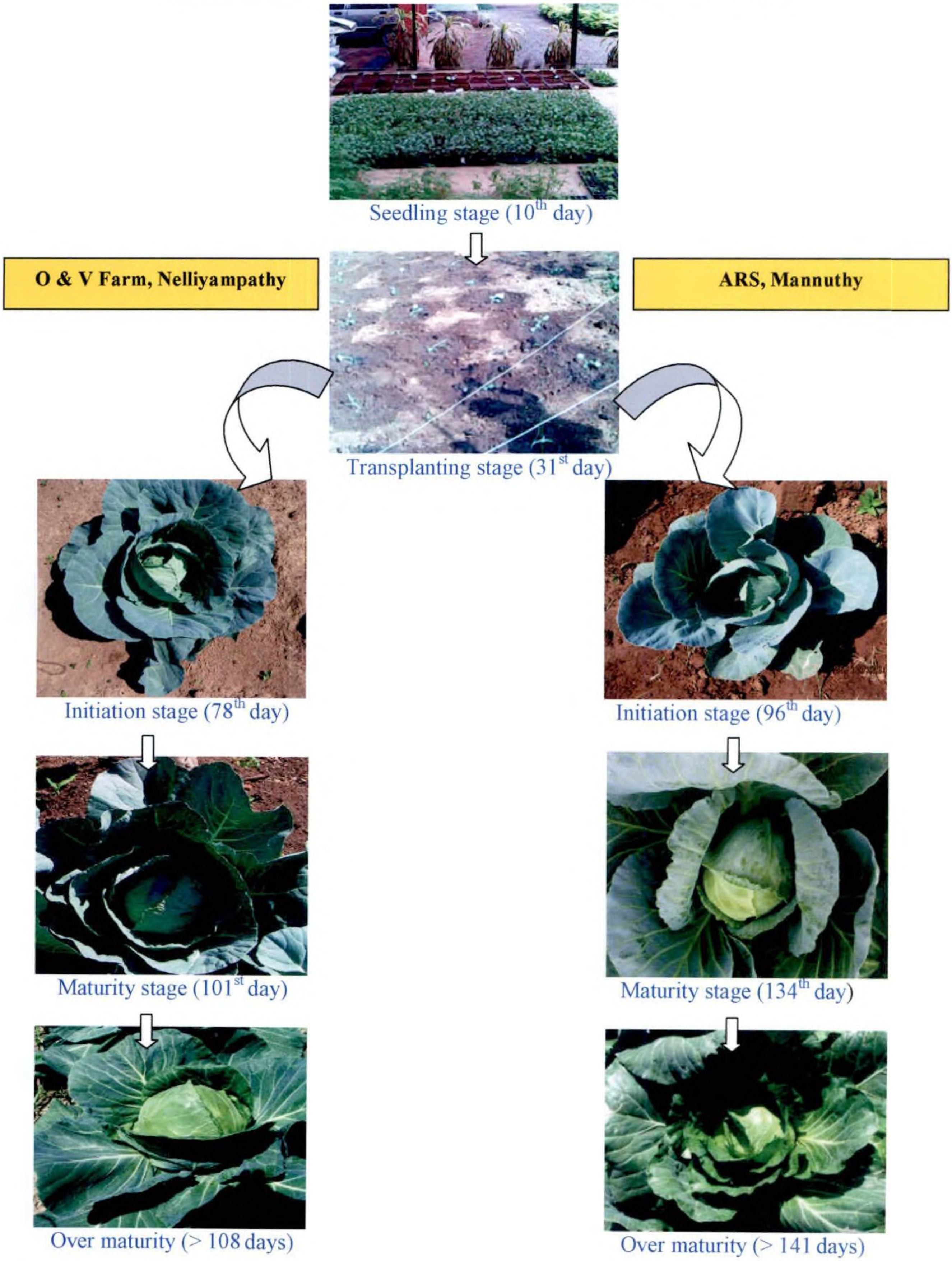
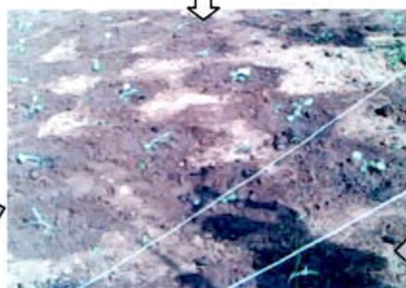


Plate 5. Developmental stages of cauliflower

Seedling stage (10^{th} day)



Transplanting stage (31^{st} day)

O & V Farm, Nelliyampathy

Initiation stage (65^{th} day)

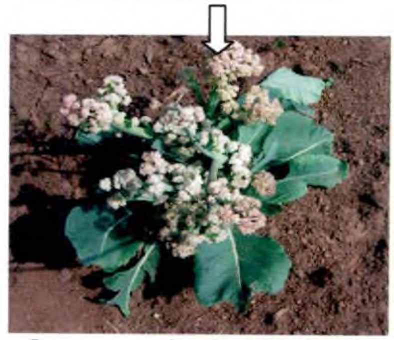
Maturity stage (91^{st} day)

Over maturity (> 98 days)

ARS, Mannuthy

Initiation stage (93^{rd} day)

Maturity stage (130^{th} day)



Over maturity (> 137 days)

Plate 8. Physiological disorders during storage

Plate 8a. Browning

Plate 8b. Yellowing

Table 5. Mean scores for organoleptic qualities of cabbage, genotype Tropical Sun Plus

Character / Region	Colour			Taste			Flavour			Texture			Overall acceptability		
	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value
Hills	4.16 (1.25)	3.26 (1.35)	13.5**	3.5 (1.08)	2.6 (1.02)	4.92**	3.3 (1.17)	2.5 (1.15)	5.43**	3.6 (1.17)	2.8 (1.25)	6.53**	3.98 (1.0)	3.01 (1.0)	97.0**
Plains	4.66 (1.75)	3.73 (1.75)	46.5**	4.5 (1.92)	3.6 (1.95)	3.89**	4.6 (1.83)	3.7 (1.83)	3.53**	4.3 (1.83)	3.5 (1.75)	4.61**	4.75 (2.0)	3.75 (2.0)	63.2**
Kendall's W (a)	0.5	0.7		0.83	0.85		0.66	0.76		0.5	0.5		1.0	1.0	
% Significant	0.083	0.073		0.025	0.027		0.046	0.051		0.083	0.083		0.014	0.016	

Mean significant at 5% level

Table 6. Mean scores for organoleptic qualities of cabbage, genotype NS 183

Character / Region	Colour			Taste			Flavour			Texture			Overall acceptability		
	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value
Hills	2.8 (1.33)	2.1 (1.31)	4.42**	3.6 (1.67)	3.1 (1.65)	2.67**	3.1 (1.58)	2.1 (1.48)	7.74**	3.1 (1.58)	3.1 (1.58)	+	3.1 (1.42)	3.03 (1.43)	NS
Plains	3.16 (1.67)	2.19 (1.62)	35.4**	3.0 (1.33)	2.7 (1.35)	NS	3.0 (1.42)	1.9 (1.32)	2.39**	2.8 (1.42)	2.12 (1.23)	90.3**	3.04 (1.66)	2.85 (1.63)	NS
Kendall's W (a)	0.33	0.38		0.16	0.18		0.03	0.029		0.05	0.051		0.03	0.04	
% Significant	0.15	0.17		0.31	0.34		0.65	0.66		0.56	0.53		0.65	0.80	

Values in parenthesis are mean rank scores
** Significant at 1% level
+ 't' test not performed as all observation were equal
NS - Non significant

the plains. But the mean scores obtained one week after storage for various quality attributes like colour (3.73), taste (3.6), texture (3.5), flavour (3.7) and overall acceptability (3.75) was significantly lower as compared to scores obtained before storage.

4.1.1.1.6.2 Genotype NS 183

The mean scores obtained for various qualities attributes like colour, flavour, texture, taste and overall acceptability of cabbage, genotype NS 183 before storage and one week after storage are presented in Table 6. Scores obtained for different quality attributes of cabbage genotype NS 183 was not statistically significant between the regions.

Comparatively high mean score for taste (3.6), flavour (3.1) and texture (3.1) was recorded in cabbage genotype NS 183 raised in the hills. There was no significant difference in overall acceptability of the selected cabbage genotypes when grown in hills and plains.

The mean scores obtained for various qualities attributes like colour, flavour, texture, taste and overall acceptability of cabbage genotype NS 183 recorded one week after storage was also not statistically significant between regions. Comparatively higher score for taste (3.1), flavour (2.1) and texture (3.1) was recorded in cabbage genotype NS 183 raised in the hills. There was significant reduction in quality attributes like colour and flavour in the produce from both regions when observed one week after storage. However there was no variation in overall acceptability before and after storage.

4.1.1.1.7 Physiological disorders

Occurrence of physiological disorders or decay of cabbage was determined by visual observation. Browning was noticed in the genotypes NS 160 and NS 35 grown in both the regions (Plate 6b).

Table 7. Comparison of days to maturity (days) of cauliflower genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 133	93.16 (9.6) [c]	132.00 (11.51) [b]	350.68**
2	Basant	91.20 (9.5) [d]	132.16 (11.51) [c]	191.81**
3	NS 60 N	83.88 (9.1) [a]	132.00 (11.51) [b]	725.43**
4	Pusa Meghna	85.72 (9.2) [b]	128.16 (11.34) [a]	242.34**

Table 8. Comparison of curd yield (Kg/16 m^2 plot) of cauliflower genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 133	26.4 (5.10) [a]	0.87 (1.17) [b]	55.008**
2	Basant	21.0 (4.60) [d]	0.86 (1.16) [c]	24.799**
3	NS 60 N	23.2 (4.86) [b]	1.43 (1.38) [a]	22.896**
4	Pusa Meghna	22.8 (4.82) [c]	0.78 (1.13) [d]	41.396**

Figures in parentheses are SQRT transformed values

** Significant at 1% level

4.1.1.2 Cauliflower

4.1.1.2.1 Days to maturity

In cauliflower, genotype NS 60N matured early in hilly region (83.88 days) than in plains (Table 7). This particular genotype was an early maturing type compared to all the other genotypes raised in hills. In plains, Pusa Meghna matured early (128.16 days) than all other genotypes but the yield characters were not promising. There was significant variation in days to maturity between cauliflower genotypes grown in hills and plains. Harvest maturity was delayed by 39 – 49 days when the crop was raised in the plains (Plate 5).

4.1.1.2.2 Curd yield

Cauliflower grown in hills gave significantly higher yield irrespective of genotypes compared to plains. Among the cauliflower genotypes grown in hilly region, NS 133 recorded the highest curd yield (26.4 Kg/16 m^2 plot). In plains, the yield was very less for all the genotypes but significant difference was noticed between the genotypes (Table 8). Highest curd yield (1.43 Kg/16 m^2 plot) was observed in NS 60N and lowest (0.78 Kg/16 m^2 plot) in Pusa Meghna in plains.

4.1.1.2.3 Curd weight

Cauliflower genotype NS 133 recorded the highest curd weight (800 g) in hilly region. In plains, curd weight was very less for all the genotypes but significant difference was noticed between the genotypes for curd weight (Table 9). Among the genotypes grown in the plains, NS 60N recorded the maximum (82 g) and NS 133 the minimum (34 g) curd weight.

4.1.1.2.4 Curd height

The highest curd height (13.93 cm) was recorded for cauliflower genotype NS 133 when grown in hilly region (Table 10). NS 60N recorded more height (8.15 cm) compared to all the other genotypes raised in plains. There was a significant reduction in curd height when the same genotype was raised in plains.

Table 9. Comparison of curd weight (g) of cauliflower genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 133	800 (28.2) [a]	34 (5.8) [d]	22.663**
2	Basant	610 (24.7) [d]	41 (6.4) [c]	21.017**
3	NS 60 N	650 (25.5) [b]	82 (9.0) [a]	16.899**
4	Pusa Meghna	630 (25.1) [c]	62 (7.9) [b]	20.647**

Table 10. Comparison of curd height (cm) of cauliflower genotypes grown in hills and plains

Sl. No.	Genotypes	Hills	Plains	t value
1	NS 133	13.93 (3.78) [a]	6.95 (2.72) [b]	29.899**
2	Basant	12.32 (3.50) [d]	6.37 (2.62) [d]	19.722**
3	NS 60 N	12.80 (3.60) [c]	8.15 (2.94) [a]	22.334**
4	Pusa Meghna	13.25 (3.71) [b]	6.92 (2.72) [c]	22.972**

Figures in parentheses are SQRT transformed values
** Significant at 1% level

4.1.1.2.5 Curd solidity

Cauliflower curd solidity was measured by visual observation. In hilly region cauliflower genotypes, (NS 133, Basant, NS 60 N and Pusa Meghna) produced firm and uniform curds but in plains curds were thicker and non uniform.

4.1.1.2.6 Sensory quality attributes of cauliflower

4.1.1.2.6.1 Genotype NS 60N

Results of organoleptic evaluation of cauliflower genotype NS 60 N before storage, with respect to colour, flavour, texture, taste and overall acceptability are presented in Table 11. Superior score for colour (4.3) was obtained for produce from hills with mean rank 1.58. Lowest score for colour was observed in produce from plains (4.0) with mean rank 1.42. NS 60N registered maximum score (4.0) for taste with mean rank 1.58 in plains. Significant difference was not noticed in texture and flavour for produce grown in hills and plains. The overall acceptability (4.08) was also highest for produce from hilly region.

After storing cauliflower for one week, organoleptic qualities of cauliflower genotype NS 60N were observed. Superior score for colour (3.5) was obtained for produce from hills with mean rank 1.58. Least score for colour was observed in produce from plains (3.3) with mean rank 1.42. NS 60N registered maximum score (3.1) for taste with mean rank 1.58 in plains. Significant difference was not noticed in texture and flavour for produce grown in hills and plains. The overall acceptability (3.1) was also highest for produce from hilly region (Table 11).

4.1.1.2.6.2 Genotype NS 133

Results of organoleptic evaluation of cauliflower genotype NS 133 with respect to colour, flavour, texture, taste and overall acceptability are presented in Table 12. Superior score for colour (3.5) was obtained for plains with mean rank

Table 11. Mean scores for organoleptic qualities of cauliflower, genotype NS 60N

Character / Region	Colour			Taste			Flavour			Texture			Overall acceptability		
	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value
Hills	4.3 (1.58)	3.5 (1.58)	6.19**	3.8 (1.42)	2.9 (1.42)	11.0**	3.6 (1.42)	3.3 (1.40)	3.67**	3.6 (1.58)	3.2 (1.58)	4.89**	4.08 (1.58)	3.1 (1.58)	16.8**
Plains	4.0 (1.42)	3.3 (1.42)	1.28**	4.0 (1.58)	3.1 (1.58)	1.65**	3.7 (1.58)	3.5 (1.49)	1.41**	3.5 (1.42)	3.1 (1.42)	2.82**	3.9 (1.42)	3.0 (1.42)	11.0**
Kendall's W (a)	0.05	0.03		0.03	0.025		0.18	0.16		0.05	0.07		0.03	0.03	
% Significant	0.56	0.56		0.65	0.80		0.35	0.31		0.56	0.66		0.65	0.65	

Table 12. Mean scores for organoleptic qualities of cauliflower, genotype NS 133

Character / Region	Colour			Taste			Flavour			Texture			Overall acceptability		
	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value	Before Storage	1 week after storage	t value
Hills	3.0 (1.42)	2.0 (1.42)	3.67**	3.7 (1.42)	3.5 (1.42)	2.01**	4.1 (1.75)	3.8 (1.75)	3.67**	3.1 (1.5)	3.1 (1.58)	+	3.4 (1.42)	3.2 (1.42)	2.3**
Plains	3.5 (1.58)	2.5 (1.58)	12.2**	3.8 (1.58)	3.5 (1.58)	2.12**	3.5 (1.25)	3.3 (1.25)	2.44**	3.0 (1.5)	2.87 (1.42)	1.23**	3.8 (1.58)	3.7 (1.58)	NS
Kendall's W (a)	0.03	0.03		0.03	0.06		0.5	0.6		0	0		0.03	0.03	
% Significant	0.65	0.65		0.65	0.56		0.083	0.092		1	1		0.65	0.65	

Values in parenthesis are mean rank scores
** Significant at 1% level
+ 't' test not performed as all observation were equal
NS - Non significant

Plate 6. Physiological disorders at O&V farm, Nelliyampathy

Plate 6a. Riceyness in cauliflower

Plate 6b. Browning in cabbage

Plate 6c. Whiptail in cauliflower

Plate 7. Physiological disorders at ARS, Mannuthy

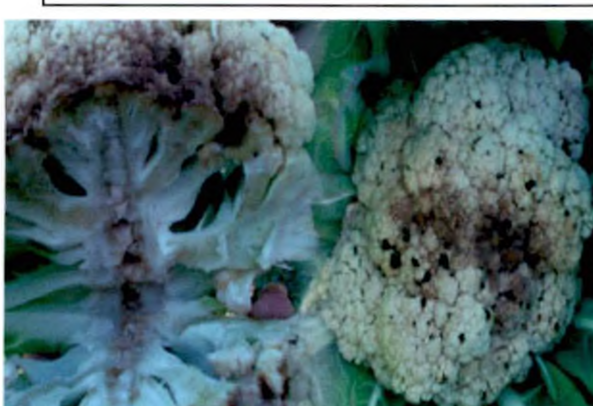


Plate 7a. Brown or black specks in cauliflower

Plate 7b. Yellowing in cauliflower

0.65. NS 133 registered the maximum score (4.1) for flavour with mean rank 1.75 when grown in hills. The overall acceptability (3.8) was more for produce grown in plains. The mean ranks on the basis of Kendall's coefficient of variation were found to be 1.58 and 1.42 for produce grown in plains and hills respectively.

Results of organoleptic evaluation of cauliflower genotype NS 133 recorded at one week after storage with respect to colour, flavour, texture, taste and overall acceptability are presented in Table 16. Superior score for colour (2.5) was obtained for plains with mean rank 1.58. The variation in the organoleptic qualities like colour, taste, flavour before and after storage was significant.

NS 133 registered the maximum score (3.8) for flavour with mean rank 1.75 when grown in hills. The overall acceptability (3.7) was more for produce grown in plains. The mean ranks on the basis of Kendall's coefficient of variation were found to be 1.58 and 1.42 for produce grown in plains and hills respectively.

4.1.1.2.7 Physiological disorders

Cauliflower genotype NS 60N raised in hilly region exhibited early maturation, looseness of curd and flower stalk emergence (Plate 6a). Black or brown speck was the serious problem observed in all the cauliflower genotypes when grown in plains (Plate 7a). The symptoms were appearance of necrotic lesions on the surface of branches as well as flower stalks. NS 60N exhibited whiptail symptoms when raised in plains (Plate 6c). In all the cauliflower genotypes, yellowing was noticed in plains (Plate 7b).

Yield attributes

Cabbage genotype NS 183 exhibited better performance when grown in high altitude region with respect to high head yield, head weight, head height, head solidity and days to maturity. In cauliflower, genotype NS133 performed best in high altitude region with respect to high curd yield, curd weight, curd height and curd solidity.

Cabbage genotype TSP exhibited superior performance in plains. This genotype recorded high head yield, head weight, head height and head solidity. High curd yield, curd weight, curd height and curd solidity was observed in cauliflower genotype NS 60N, indicating that it is an ideal variety for cultivation in the plains.

4.1.2 Biochemical characters

Biochemical characters of cabbage and cauliflower grown in hills and plains were analyzed. The constituents analysed were moisture, acidity, ascorbic acid, protein and minerals (phosphorus, calcium and potassium).

4.1.2.1 Moisture content

The moisture content of cabbage and cauliflower was determined using a digital moisture meter. Cabbage genotype TSP recorded 90.59% moisture when grown in plains. The corresponding moisture content for genotype NS 183 when grown in hills was 87.69% (Table 13).

No significant difference was recorded in case of moisture content between cauliflower genotype (Table 14).

4.1.2.2 Acidity

The acidity of cabbage genotypes NS 183 and TSP was 0.144% and 0.071% respectively. No significant difference was recorded in case of acidity between cauliflower genotype.

4.1.2.3 Ascorbic acid

There was significant decrease in ascorbic acid content in cabbage and cauliflower during storage (Table 13 & 14). Ascorbic acid was found to decrease with increase in the duration of storage. Variation in ascorbic acid content between the genotypes was significant in the case of both cabbage and cauliflower. Before storage higher level of ascorbic acid was recorded (51.80 mg/ 100g) in genotype NS 183 than in genotype TSP (12.92 mg/ 100g). After one

Table 13. Biochemical characteristics of cabbage

Sl. No.	Characters	NS 183	TSP	t value
1	Moisture content (%)	87.69	90.59	3.4468**
2	Acidity (%)	0.144	0.071	8.9630**
3	Ascorbic acid (mg/100g)			
	i) Before storage	51.80	12.92	29.660**
	ii) After one week of storage	37.67	9.17	24.561**
4	Protein (g/100g)	0.73	0.65	1.5452**
5	Phosphorus (mg/100g)	26	14	40.045**
6	Calcium (mg/100g)	42	110	8.7505**
7	Potassium (mg/100g)	200	197	NS

Table 14. Biochemical characteristics of cauliflower

Sl. No.	Characters	NS 133	NS 60N	t value
1	Moisture content (%)	79.14	79.08	NS
2	Acidity (g/100g)	0.119	0.117	NS
3	Ascorbic acid (mg/100g)			
	i) Before storage	38.85	8.65	22.982**
	ii) After one week of storage	19.15	6.91	8.2604**
4	Protein (g/100g)	0.89	0.82	3.7742**
5	Phosphorus (mg/100g)	11	21	8.1649**
6	Calcium (mg/100g)	19	29	8.1649**
7	Potassium (mg/100g)	320	253	24.533**

** Significant at 1% level
NS Non Significant

week of storage, ascorbic acid content decreased in NS 183 (37.67 mg/ 100g) and TSP (9.17 mg/ 100g). Before storage, ascorbic acid content was recorded comparatively high (38.85mg/ 100g) in cauliflower genotype NS 133. A decline in ascorbic acid content after storage was observed in genotypes NS 133 (19.15mg/ 100g) and NS 60N (6.91mg/ 100g).

4.1.2.4 Protein

The protein content of cabbage and cauliflower was determined by Lowry's method. Cabbage genotype NS 183 recorded higher protein content (0.73 g/100g) than TSP (0.65 g/100g). In the case of cauliflower, genotype NS 133 recorded higher protein content (0.89 g/ 100g) than NS 60N (0.82 g/ 100g). These results are shown in table 13 and 14.

4.1.2.5 Phosphorus

The phosphorus content was analysed colorimetrically. Phosphorus content was comparatively high in cabbage genotype NS 183 (26 mg/100g) than TSP (14 mg/100g). The phosphorus content recorded in the cauliflower genotypes NS 60N and NS 133 was 21 mg/100g and 11 mg/100g respectively (Table 13 and 14).

4.1.2.6 Calcium

Cabbage genotype TSP recorded higher calcium content (110 mg/100g) than NS 183 (42 mg/100g). In case of cauliflower, genotype NS 60N recorded a higher calcium content (29 mg/100g) than NS 133 (19 mg/100g). These results are shown in table 13 and 14.

4.1.2.7 Potassium

The potassium content was estimated using flame photometer. No significant difference was recorded in case of potassium content between the cauliflower genotype. Relatively high potassium content (320 mg/100g) was

Table 15. Effect of packaging and storage condition on PLW% and shelf life of NS 183

Sl. No.	Characters	Temperature	Control	Cling film package	t value
1	PLW (%)	0 to -1°C	13.95	10.05	13.070**
		4 to 6°C	18.70	10.15	141.84**
		Ambient	22.55	12.10	168.05**
2	Shelf life (days)	0 to -1°C	14.50	16.75	37.327**
		4 to 6°C	8.00	9.50	1.2970**
		Ambient	7.00	7.75	NS

Table 16. Effect of packaging and storage condition on PLW% and shelf life of Tropical Sun Plus

Sl. No.	Characters	Temperature	Control	Cling film package	t value
1	PLW (%)	0 to -1°C	4.00	2.00	1.5490**
		4 to 6°C	29.50	11.20	100.23**
		Ambient	34.65	17.70	282.23**
2	Shelf life (days)	0 to -1°C	18.00	21.00	3.6742**
		4 to 6°C	12.50	17.00	7.7555**
		Ambient	9.50	14.00	9.4793**

** Significant at 1% level
NS Non significant

Plate 9. Storage of whole cabbage

Plate 9a. Control

Plate 9b. Cling film

Plate 10. Storage of whole cauliflower

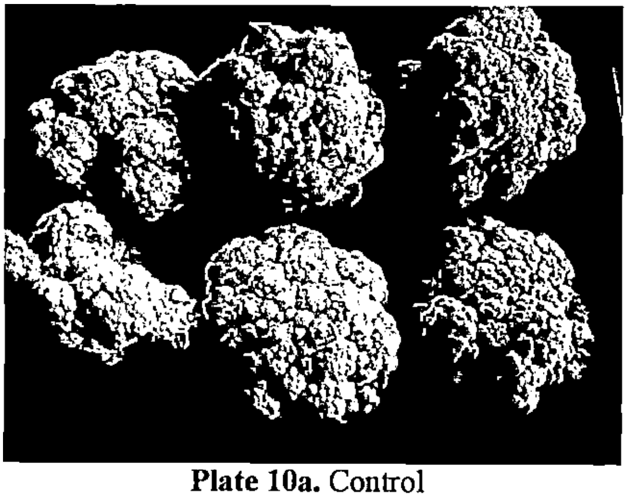


Plate 10a. Control

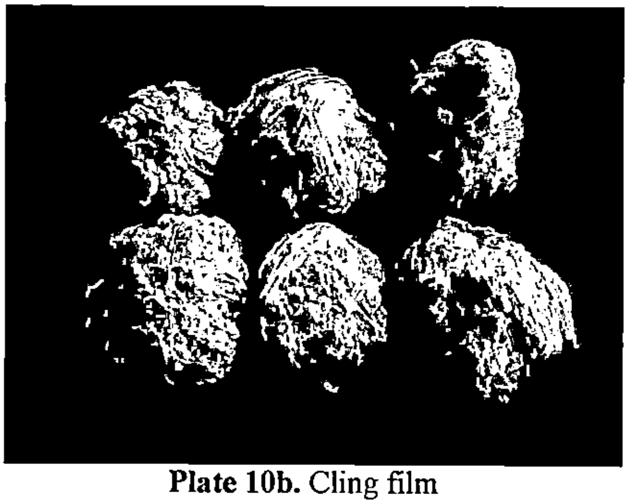


Plate 10b. Cling film

observed in cauliflower genotype NS 133 than NS 60N (253 mg/100g) as shown in table 13 and 14.

4.2 Evaluation of storage qualities

The genotype which performed well in terms of yield and quality both in plains and higher altitude were used for storage studies.

4.2.1 Whole produce

Cabbage and cauliflower immediately after harvest were packaged with cling film and stored for a period of one to two weeks under three temperature regimes (0 to -1° C, 4 to 6°C and ambient temperature). Weight of fresh cabbage and cauliflower was recorded before storage and at the end of storage period. Shelf life was recorded by noting the colour change and decay of the produce. In cabbage yellowish discolouration, decay and disorder were observed one week after storage, in both cling film packaged produce as well as control when stored at 4 to 6°C and at ambient condition. In the case of cauliflower, brown spot, brownish discolouration, decay and disorder were observed one week after storage, in both cling film packaged produce as well as control when stored at 4 to 6°C and at ambient condition (Plate 9& 10).

4.2.1.1 Effect of storage condition on cabbage genotype NS 183

Physiological loss in weight (PLW %) was comparatively higher in control when stored under ambient condition than at 0 to -1° C and 4 to 6°C .When whole produce was wrapped with cling film and stored at 0 to -1° C less percentage of PLW (10.05 %) was observed one week after storage.

The longest shelf life (16.75 days) was obtained in cling film package under 0 to -1°C temperature regime. Least shelf life (7 days) was recorded in non packaged material stored in ambient condition (Table 15).

Table 17. Effect of packaging and storage condition on postharvest PLW% and shelf life of NS 133

Sl. No.	Characters	Temperature	Control	Cling film package	t value
1	PLW (%)	0 to -1°C	7.350	2.13	639.31**
		4 to 6°C	23.05	5.40	302.46**
		Ambient	52.60	29.05	405.87**
2	Shelf life (days)	0 to -1°C	11.50	16.00	7.7555**
		4 to 6°C	7.00	8.50	2.5851**
		Ambient	7.25	8.00	21.543**

Table 18. Effect of packaging and storage condition on PLW% and shelf life of NS 60N

Sl. No.	Characters	Temperature	Control	Cling film package	t value
1	PLW (%)	0 to -1°C	6.90	2.40	19.595**
		4 to 6°C	42.50	17.60	304.96**
		Ambient	45.25	19.05	2841.4**
2	Shelf life (days)	0 to -1°C	18.50	22.50	49.986**
		4 to 6°C	8.20	16.00	13.442**
		Ambient	4.00	5.10	1.8958**

** Significant at 1% level

4.2.1.2 Effect of storage condition on cabbage genotype Tropical Sun Plus

In the genotype Tropical Sun Plus, PLW was lowest (2.0 %) in cling film package, stored at 0 to -1° C. Highest percentage of PLW (34.65 %) was recorded in control treatment stored at ambient condition. The longest shelf life of 21 days was obtained in cling film package stored at 0 to -1° C. Shelf life was least (9.5 days) when stored at ambient condition without cling film packaging (Table 16).

4.2.1.3 Effect of storage condition on cauliflower genotype NS 133

In cauliflower genotype NS 133, PLW (%) was least (2.13 %) in cling film packaged material stored at 0 to -1° C. Higher percentage of PLW (52.6 %) was recorded in control treatment when stored at ambient condition. Shelf life was extended (16 days) by packaging and storing at very low temperature (0 to -1° C). Least shelf life (7.25 days) recorded in control treatment stored under ambient condition (Table 17).

4.2.1.4 Effect of storage condition on cauliflower genotype NS 60N

Percentage of PLW (2.4 %) was least in cling film package (NS 60N) when stored at 0 to -1° C. The recorded PLW (45.25 %) was highest in control treatment when stored under ambient condition.

The shelf life (22.5 days) was longest in cling film package when stored at 0 to -1° C. Least shelf life of 4 days was recorded for control when stored under ambient condition (Table 18).

4.2.2 Minimally processed produce

After washing cabbage was shredded and in case of cauliflower was separated to individual florets. Both were immersed in two percent warm salt water for 10 minutes, air dried and packed in different packaging materials like high density polyethylene, aluminum tray over wrapped with cling film and polypropylene (Plate 11& 12). They were stored under different temperature regimes for a period of two weeks. In cabbage, yellowish discolouration, decay

Table 19. Effect of packaging and storage conditions on PLW% and shelf life of minimally processed NS 183

SL. No.	Character	Storage Temperature	Control	HDPE	ATWCFP	Polypropylene
1	PLW%	0 to -1°C	45.0	0	0	0
		4 to 6°C	50.0	0	0	0.5
		Ambient	84.5 (9.24)[c]	2.00 (1.47)[a]	10.0 (3.23)[b]	2.50 (1.73)[a]
2	Shelf life	0 to -1°C	4.50 (2.2)[c]	6.00 (2.53)[c]	5.50 (2.44)[c]	5.50 (2.44)[c]
		4 to 6°C	3.00 (1.86)[c]	4.00 (2.08)[c]	3.50 (1.98)[c]	4.00 (2.11)[c]
		Ambient	1.00 (1.18)[b]	3.25 (1.95)[a]	2.0 (1.56)[ab]	2.00 (1.56)[ab]

Table 20. Effect of packaging and storage conditions on PLW% and shelf life of minimally processed Tropical Sun Plus

SL. No.	Character	Storage Temperature	Control	HDPE	ATWCFP	Polypropylene
1	PLW%	0 to -1°C	5.50	0	0	0
		4 to 6°C	19.0	0	0	0
		Ambient	9.0 (8.92)[b]	3.50 (1.99)[a]	9.50 (3.16)[b]	3.50 (1.99)[a]
2	Shelf life	0 to -1°C	15.5 (3.99)[c]	20.75 (4.6)[a]	18.0 (4.29)[b]	20.5 (4.58)[a]
		4 to 6°C	3.42 (1.89)[c]	3.50 (1.99)[c]	3.50 (1.99)[c]	4.00 (2.09)[c]
		Ambient	1.5 (1.46)[ab]	2.00 (1.56)[a]	1.25 (1.31)[b]	1.25 (1.32)[b]

Figures in parentheses are SQRT transformed values

Plate 11. Storage of minimally processed cabbage in different packaging materials

Plate 11a. Polypropylene

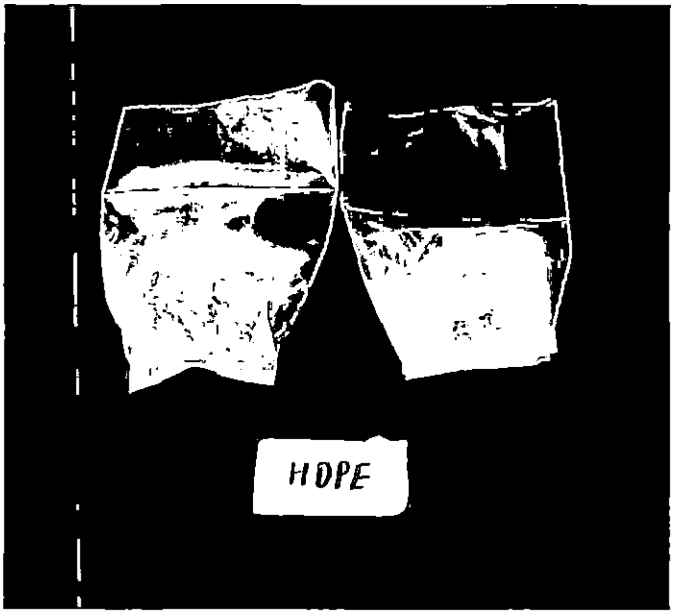


Plate 11b. HDPE

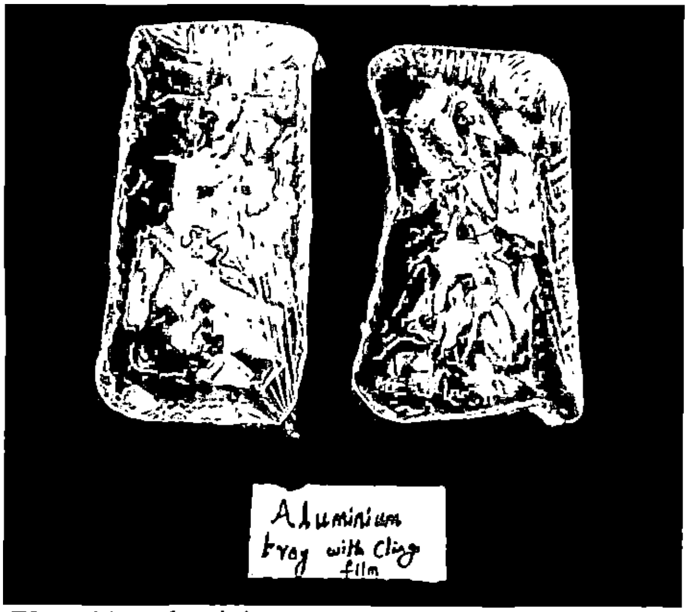


Plate 11c. Aluminium tray wrapped with cling film

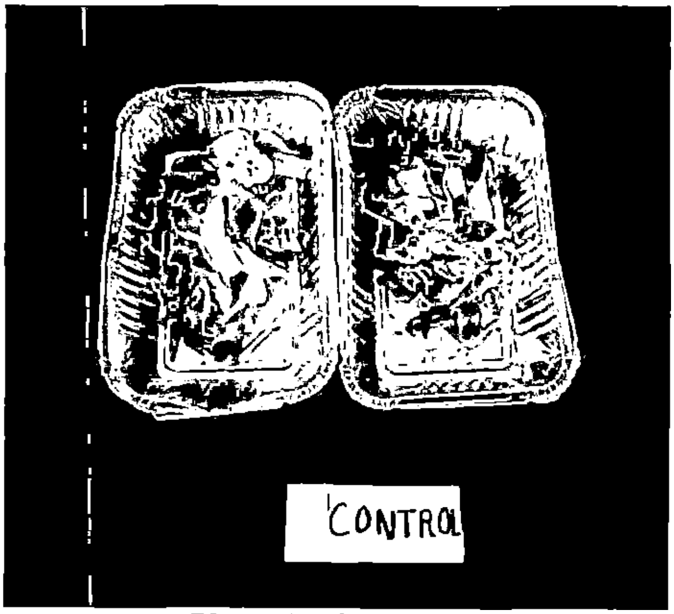


Plate 11d. Control

and disorder were observed at second day of storage, in both cling film as well as control when stored at 4 to 6°C and at ambient condition. In cauliflower brown spot, brownish discolouration, decay and disorder were observed at second day of storage, in both cling film as well as control when stored at 4 to 6°C and at ambient condition.

No physiological loss in weight was observed in minimally processed cabbage packaged in polypropylene, high density polyethylene, aluminum tray over wrapped with cling film package and stored at temperature regimes of 0 to -1°C and 4 to 6°C.

4.2.2.1 Effect of storage condition on cabbage genotype NS 183

Percentage of physiological loss in weight was less in produce packaged in high density polyethylene (2.0 %) as well as polypropylene (2.5 %) and stored at ambient temperature. PLW (%) was very high (84.5 %) for non packaged produce stored at ambient temperature.

Significantly longer shelf life was obtained when stored at temperature regime of 0 to -1°C in all the treatments. But longest shelf life (6 days) was obtained when stored under 0 to -1°C in HDPE package. Least shelf life (1.25 days) was recorded when the produce was stored at ambient condition without any packaging (Table 19).

4.2.2.2 Effect of storage condition on cabbage genotype Tropical Sun Plus

Physiological loss in weight was not observed in packaged samples stored both at 0 to -1°C and 4 to 6°C. PLW (%) was less in minimally processed cabbage packaged with high density polyethylene as well as polypropylene under ambient temperature.

The shelf life was longer in HDPE package (20.75 days) followed by polypropylene (20.5 days) when stored at 0 to -1°C compared to ambient temperature (3.5 days). No significant difference was noticed in case of shelf life for all the packaging materials stored at 4 to 6°C. Least shelf life (1.25 days) was

Table 21. Effect of packaging and storage conditions on PLW% and shelf life of minimally processed NS 133

SL. No.	Character	Storage Temperature	Control	HDPE	ATWCFP	Polypropylene
1	PLW%	0 to -1°C	45.5	0	0	0
		4 to 6°C	79.0	0	2.5	0
		Ambient	85.0 (9.24)^{b}	10.0 (3.21)^{a}	10.1 (3.22)^{a}	12.50 (3.6)^{a}
2	Shelf life	0 to -1°C	4.00 (2.08)^{c}	6.00 (2.53)^{c}	5.00 (2.32)^{c}	6.50 (2.64)^{c}
		4 to 6°C	2.00 (1.56)^{b}	4.50 (2.23)^{a}	3.00 (1.81)^{ab}	3.50 (1.99)^{ab}
		Ambient	1.25 (1.32)^{b}	3.00 (1.86)^{a}	2.00 (1.56)^{ab}	2.00 (1.56)^{ab}

Table 22. Effect of packaging and storage conditions on PLW% and shelf life of minimally processed NS 60N

SL. No.	Character	Storage Temperature	Control	HDPE	ATWCFP	Polypropylene
1	PLW%	0 to -1°C	22.5	0	0	0
		4 to 6°C	57.5	0	0	12.0
		Ambient	67.5 (8.24)^{d}	19 (4.4)^{a}	27 (5.2)^{c}	24.5 (5.0)^{b}
2	Shelf life	0 to -1°C	18.0(1.56)^{b}	22.5 (2.23)^{a}	20.5 (1.41)^{ab}	20.5 (1.34)^{ab}
		4 to 6°C	3.00 (1.85)^{b}	4.5 (2.23)^{a}	4.25 (2.17)^{a}	3.50 (1.99)^{ab}
		Ambient	2.00 (1.56)^{c}	2.25 (1.65)^{c}	1.25 (1.32)^{c}	2.00 (1.54)^{c}

Figures in parentheses are SQRT transformed values

Plate 12. Storage of minimally processed cauliflower in different packaging materials

Plate 12a. Polypropylene

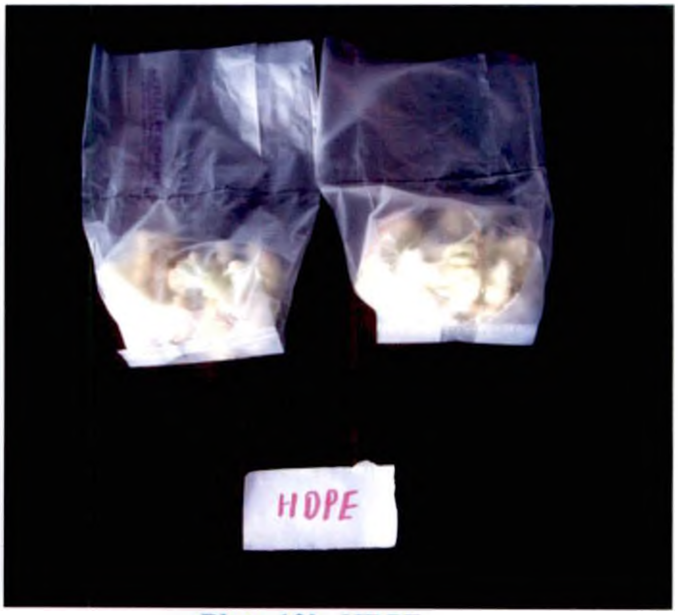


Plate 12b. HDPE

Plate 12c. Aluminium tray wrapped with cling film

Plate 12d. Control

recorded in both polypropylene as well as aluminum tray over wrapped with cling film package stored at ambient condition (Table 20).

4.2.2.3 Effect of storage condition on cauliflower genotype NS 133

Physiological loss in weight was less in all the packaged produce under stored at ambient temperature. The non packaged produce exhibited very high PLW (85 %) at ambient temperature. Packaging coupled with low temperature storage (0 to -1°C and 4 to 6°C) significantly reduced the PLW%.

The shelf life was longer in HDPE packaged produce when stored at 4 to 6°C (4.5 days) and at ambient temperature (3 days). No significant difference was noticed in case of shelf life for all the packaged materials stored at 0 to -1°C. Least shelf life (1.25 days) was recorded in non packaged produce stored at ambient condition (Table 21).

4.2.2.4 Effect of storage condition on cauliflower genotype NS 60 N

Physiological loss in weight (19 %) was comparatively less in produce packaged in high density polyethylene and stored at ambient temperature. The shelf life was longest in HDPE packaging (22.5 days) and storage at 0 to -1°C.

No significant difference was noticed between treatments (packaging materials) on the shelf life of minimally processed cauliflower stored at ambient temperature. At 4 to 6°C, HDPE (4.5 days) as well as polypropylene (4.25 days) packaged material exhibited comparatively longer shelf. Least shelf life (1.25 days) was recorded in polypropylene packaged produce stored at ambient condition (Table 22).

4.3 Weather parameters

Weather parameters were collected from weather recording station of Vegetable and Orange farm, Nelliyampathy and ARS, Mannuthy. The weather parameters were recorded for entire duration of cabbage and cauliflower grown in hills and plains. The total rainfall was higher (516 mm) in hills when compared to plain (464.6 mm). In hills, average maximum and minimum temperature was 23.81°C and 15.77°C respectively, whereas in plains it was 30.56°C and 21.06°C respectively (Appendix II & III). The recorded temperature was comparatively higher in plains. The average relative humidity recorded was 77.5% in hills and 63% in plains.

Discussion

5) DISCUSSION

Cabbage (*Brassica oleracea* var. *capitata* L.) and cauliflower (*Brassica oleracea* var. *botrytis* L.) members of Brassicaceae family are economically and nutritionally important cole crops, grown in more than 90 countries of the world (Chiang *et al.*, 1993). Cabbage is one of the most important cole crops grown under temperate climate for seed production (Singh *et al.*, 2010). It is grown extensively under tropical climate in North India for vegetable purpose but to a limited extend in South India. Cauliflower is one of the most widely grown cool season vegetable crops of India. With the evolution of tropical cauliflower, it is now being grown during summer and rainy season (Sharma *et al.,* 2006). Cruciferous vegetables are important source of dietary nutrients and antioxidants.

The results of experiments conducted are discussed in this chapter

5.1 Evaluation of Cabbage and cauliflower genotypes

Four genotypes each in cabbage (NS183, NS160, NS 35 and Tropical Sun Plus) and cauliflower (NS 60 N, NS133, Pusa Meghna and Basant) were evaluated both in hills and plains for yield and yield attributes as well as organoleptic qualities.

5.1.1 Physical characteristics:

5.1.1.1 Days to maturity

Isenberg *et al.* (1975) considered attaining maximum head size as an index of cabbage maturity. Accordingly cabbage and cauliflower maturity was recorded by observing compactness and maximum size of the head or curd. In cabbage genotype NS 183 matured early in hilly region whereas in the plains, cabbage genotypes took longer time (30 -33 days) to reach harvest maturity than hilly region (Fig 1a). In the case of cauliflower, genotypes matured early in hilly region than in plains. Harvest maturity was delayed by 39 – 45 days in plains. Among the different cauliflower genotypes, NS 60N matured early in hilly region (Fig 2a). In

Fig. 1 Variation in yield and yield attributes of cabbage from hills and plains

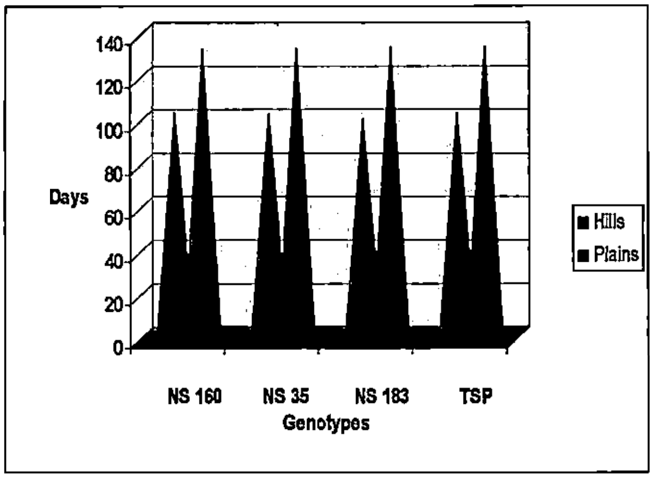


Fig. 1a Days to maturity

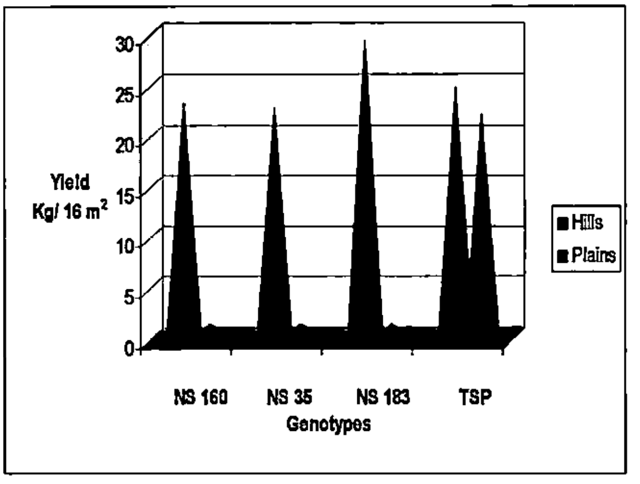


Fig. 1b Head yield

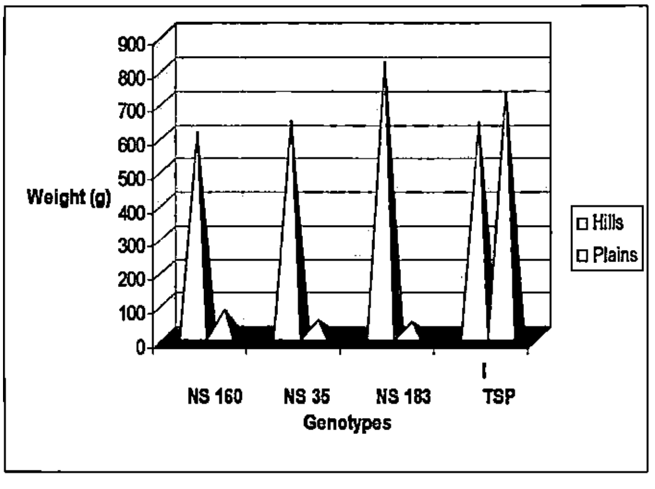


Fig. 1c Head weight

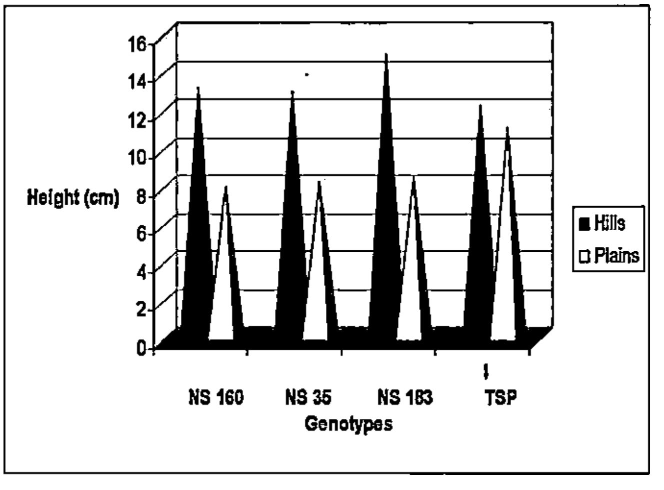


Fig. 1d Head height

plains, genotype Pusa Meghna matured early than all other genotypes. Similar studies done by, Isenberg *et al.* (1975) shown that varietal selection, growing conditions and cultural practices will affect the maturity date.

5.1.1.2 Head/ curd yield

Significant differences were observed in head yield which ranged from 22.6 – 29.3 kg /16m^2 plot in hills, whereas in plains it ranged from 1.27 – 22.06 kg /16m^2 plot. The cabbage genotype NS 183 recorded the highest head yield (29.3 Kg /16^{2}m plot) in hilly region (Fig 1b). However in plains TSP recorded the highest yield among the different genotypes. Significant positive correlation was reported by Sharma *et al.* (1982) between genotype and yield. Parmar *et al.* (1999) and Tiwari *et al.* (2003) reported that cabbage head yield and quality is influenced by several factors such as the plant genotype, climate condition, soil, water regime and nutrient status. Similarly, Chauhan (1995) reported that cabbage yield varies considerably according to season, variety and localities.

The genotypes NS 183, NS 160 and NS 35 did not perform well in the plains which is evident from the low yield recorded for these genotypes (1.27 - 1.38 Kg /16m^2). This is in consonance with the finding of Chauhan (1995) who reported that dry hot weather may gave rise to small hard head. The genotype TPS exhibited a comparatively stable in yield both in hills and plains indicating that it is ideal for cultivation in both the regions. The genotype NS 183 recorded the highest yield in hilly region, but very low yield in plains and hence could be recommended for cultivation in higher altitudes only.

Significant interaction was observed between genotypes and planting time with respect to the yield. In cauliflower, significant differences were observed in curd yield ranging from 21 – 26.4 kg /16 m^2 plot in hills and 0.78 – 1.43 kg /16 m^2 plot in plains (Fig 2b). Among the cauliflower genotypes grown in hilly region, NS 133 recorded the highest curd yield. In plains, the yield was very less for all the genotypes, which was probably due to the unfavourable weather condition prevailing during the growing season. According to Chadha (2002) the growth of

Fig. 2 Variation in yield and yield attributes of cauliflower from hills and plains

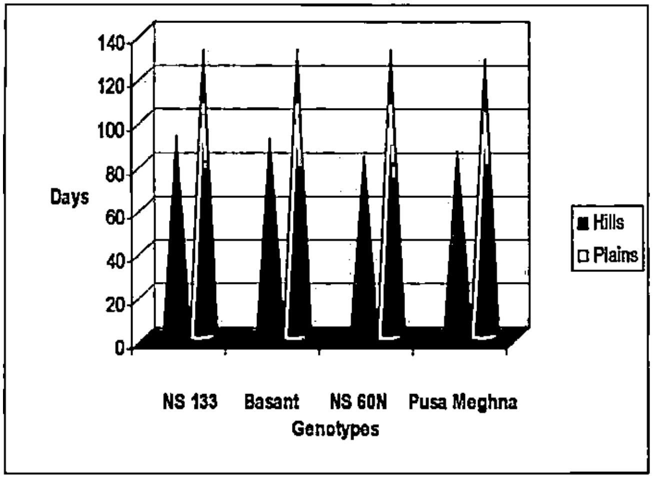


Fig. 2a Days to maturity

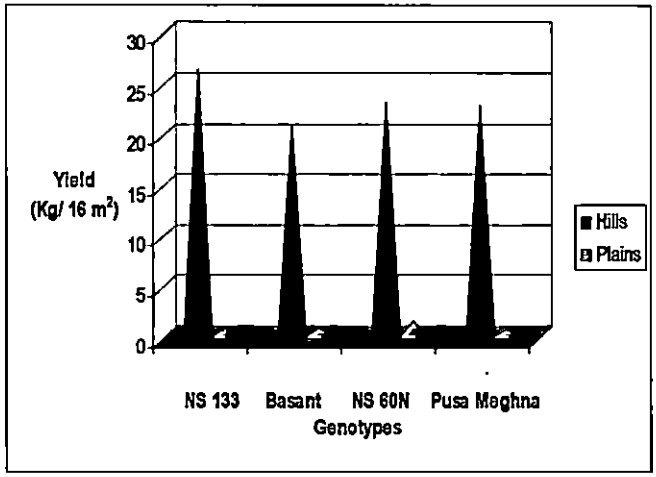


Fig. 2b Curd yield

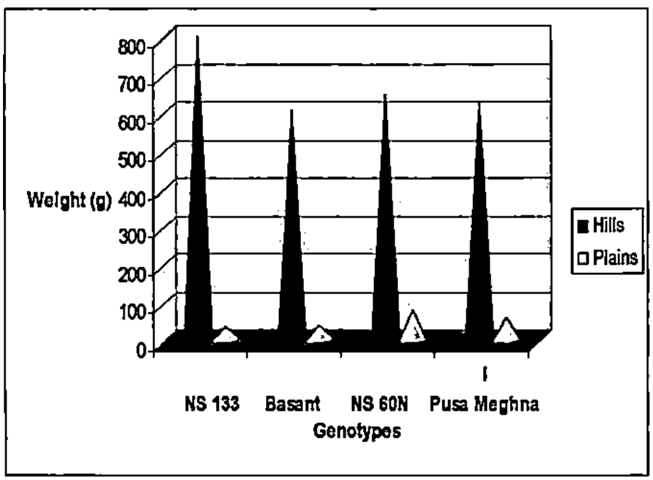


Fig. 2c Curd weight

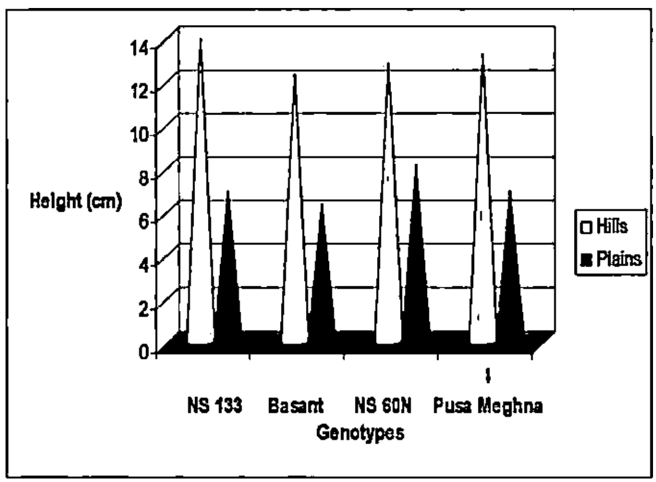


Fig. 2d Curd height

the cauliflower genotypes is arrested, when temperature rises above 25°C even in higher altitudes. Similarly, Singh (2007) reported that the optimum temperatures for curd formation are 15 - 22°C with an average maximum 25°C and minimum of 8°C. High temperature during curd maturity period promotes defective curds and deteriorate quality of curds. Chaubey *et al.* (2006), reported that climate play a significant influence on expression of characters. According to Pradeepkumar *et al.* (2002) the tropical cauliflower types, difference of 20 days in planting resulted in drastic reduction in production of curds and its size.

The planting date and season was found to affect total and marketable yield of genotypes. Demoel and Everaarts (1990) has also reported similar findings. Kahn *et al.* (2007) has stated that temperatures above 24°C are not suited for cabbage production. The results of the present study pointed out that temperature is an important factor contributing to head and curd yield. The critical duration of high temperature exposure has ranged from 27.5°C and 37.4°C and caused limited growth in cabbage as well as cauliflower.

Sharma and Pathania (2007) reported that the marketable curd yield per plant exhibited a positive correlation with net curd weight, curd size index, number of leaves per plant, curd length, curd breadth and gross plant weight at genotypic and phenotypic levels. This is in consonance with the observations of Sharma *et al.* (2006) who claimed that among the traits, harvest index, curd size index, net curd weight and curd breadth should be given emphasis while selecting genotype for high curd yield in cauliflower.

5.1.1.3 Head/ curd weight

Significant variation in head weight was observed between genotypes and it ranged from 610.4 – 816.8 g in hilly region and 46.96 – 729.6 g in plains. The recorded head weight of cabbage genotype, NS 183 was highest in hilly region. TSP recorded highest head weight compared to all the other genotypes raised in plains (Fig 1c). This may be due to efficient utilization of limiting factors like nutrients, light, air and moisture (Semuli, 2005). The variation observed in head weight when the same genotype was grown in hills and plains was significant. There was a drastic reduction in weight in all the genotypes except TSP, when grown in plains. TSP not only recorded the highest head weight when grown in plains but also showed an increase in weight compared to that obtained at higher altitude, indicating its suitability for cultivation in plains.

Significant differences were observed in curd weight of cauliflower which ranged from 610 – 800g in hills, whereas in plains it ranged from 34 – 82 g. Cauliflower genotype NS 133 recorded the highest curd weight in hilly region. In plains, curd weight was very less for all the genotypes but significant difference was noticed between the genotypes (Fig 2c). There was considerable reduction in head weight and curd weight in all the cabbage and cauliflower genotypes grown in plains as compared to that obtained at higher altitude. This may be due to increase in the temperature, as it is directly influence curd weight (Kumar *et al.*, 2004). Similar studies conducted at RARS, Ambalavayal Kerala, 974m above MSL, has shown that normal curd formation obtained when planted during the month of October. The result is in conformity with the findings of Howe and Water (1994) who reported that abiotic growth factors influence crop maturity, quantitative and qualitative changes in head. Similar observations were also made by Fujiwara *et al.* (2003).

5.1.1.4 Head/ curd height

Significant differences were observed in head height which ranged from 12.23 to 14.96 cm in hills, whereas in plains it ranged from 7.97 to 11.1 cm (Fig 1d). Similar observations were also reported by Fornaris and Rodriguez (1989). Cabbage genotype NS 183 registered highest value for head height in hilly region. TSP recorded highest head height compared to all the other genotypes raised in plains which indicate that cultivar and growing season influence head height development. Ghosk and Gulati (2001) reported that temperature had a significant effect on cabbage head shape as indicated by average head length/ width ratios. Similar findings were also reported by Singh *et al.* (2003).

Curd height ranged from 12.32 to 13.93 cm in hills and 6.37 – 8.15 cm in plains. The highest curd height was recorded for cauliflower genotype NS 133 when grown in hilly region (Fig 2d). NS 60N recorded more height compared to all the other genotypes raised in plains. According to Choudhury *et al.* (2004) increase in curd size and curd height may be due to high translocation of metabolites or plant nutrients in cauliflower. Selvakumar *et al.* (2007) claimed that delaying the date of sowing or improper sowing directly influenced curd height. A significant reduction in head and curd height was observed in all the cabbage genotypes (except TSP) and cauliflower genotypes, when raised in plains.

5.1.1.5 Head/ curd solidity

According to Day (1986) and Reid (1992) density is a measure of solidity and is most frequently employed as an indicator of maturity. Radovich *et al.* (2004) reported that head density is a primary indicator of horticultural maturity of cabbage. In hilly region, cauliflower genotypes (NS 133, Basant, NS 60 N and Pusa Meghna) produced firm and uniform curds but in plains curds were thicker and non uniform which may due to genetically hardwired, photoperiod or other environment factors involved (Wurr *et al.*, 1996). Similarly, Thamburaj and Singh (2005) reported that the cauliflower solidity varies depending on the season and the cultivar. In plains where temperature is above 25°C, most of the cultivars had small, loose and creamish colour curds, whereas in hills at 20°C - 25°C temperature curds get more compact and uniform size. According to Radovich *et al.* (2004) head or curd solidity is directly influenced by planting density. In the case of cabbage no significant difference was noticed in terms of head solidity for both the regions.

5.1.1.6 Physiological disorders

Browning was noticed in the cabbage genotypes NS 160 and NS 35 grown in both the regions which may be due to boron deficiency as reported by Hazra *et al.* (2011).

Cauliflower genotype NS 60N raised in hilly region exhibited looseness of curd and flower stalk emergence which may be probably due to very low temperature that can severely damage foliage and curd formation. Similarly, Hazra *et al.* (2011) reported that looseness of curds may due to poor seed stock as well as exposure to the temperature higher or lower than optimum required for particular genotype in curd development stage. According to Zhuang *et al.* (1995) and Dhindsa *et al.* (1981) the free radicals may increase the susceptibility to biotic and abiotic stresses, yellowing, wilting, ethylene synthesis and senescence of cauliflower. Black or brown specks were the serious problems observed in all the cauliflower genotypes when grown in plains. This is in agreement with the findings of Loughton and Riekels (1988) where they reported that cauliflower produced under periods of warm weather and less relative humidity had black or brown specks. Genotype NS 60N exhibited whiptail symptoms when raised in plains. It may be due to molybdenum deficiency, particularly in the soil with pH below 5.5 where young plants become chlorotic and finally exhibited cupping as well as withering (Hazra *et al.*, 2011).

Yield attributes

One of the basic components for characterization of plant genotypes is the estimation of productivity that often is expressed by the realized yield (Finlay and Wilkinson, 1963; Stoffela *et al.*, 1984). The results obtained in the present study showed that in cabbage genotype NS 183 is the best performing variety in higher altitude region in terms of high head yield, head weight, head height, head solidity, early maturity and better adaptivity. The result is in conformity with the findings of Mihov and Filipov (2005), who demonstrated higher yield stability and adaptability in 'Coronado' cabbage which is considered as an indication of high potential of the genotype and production conditions.

Among the cauliflower genotypes, NS133 was found to be the best in high altitude region as it recorded high curd yield, curd weight, curd height and curd solidity. Whereas in plains genotype NS 60N was found to be the best. This is

Fig. 3 Variation in organoleptic qualities between produce from hills and plains in cabbage

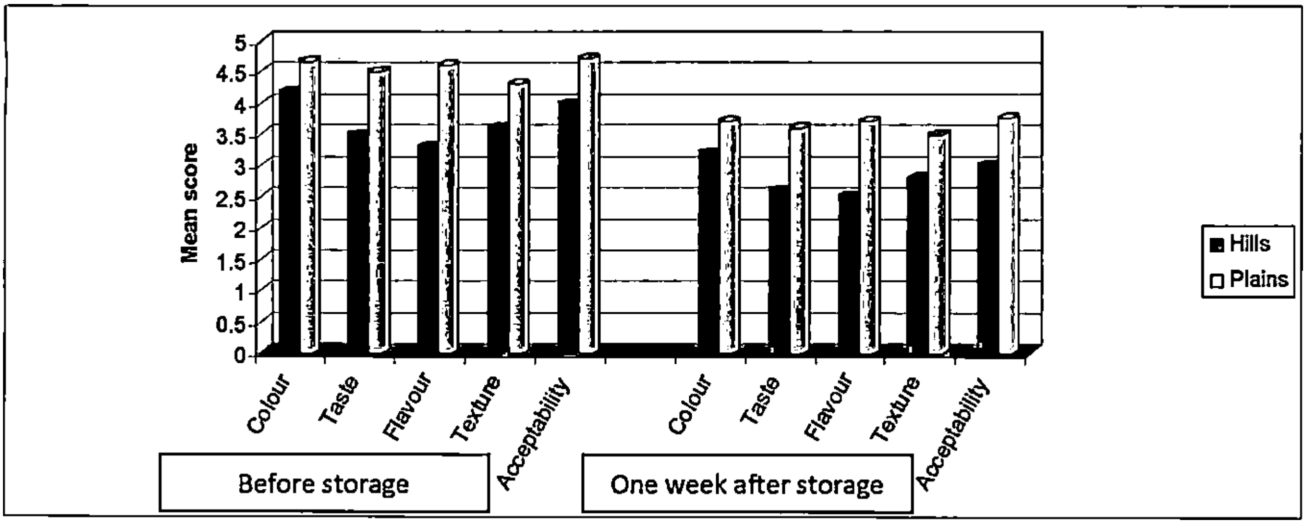


Fig. 3a Genotype Tropical Sun Plus

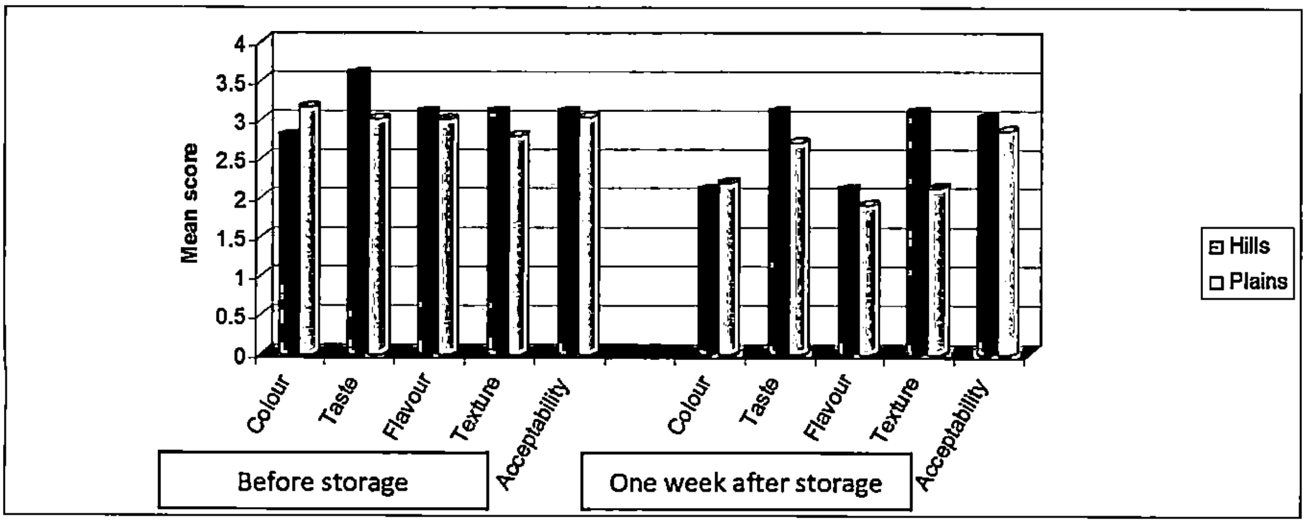


Fig. 3b Genotype NS 183

consonance with the studies of Sharma *et al.* (2005) where the genotypes of cauliflower show wide variation between plains and hills in physical characters such as curd weight, curd colour, curd compactness, harvest index and days to marketable maturity.

Strandberg and white (1979) reported that local variety traits provide key information in the selection of locally adapted cultivars and appropriate harvest dates. The important characters responsible for maximum divergence were curd weight, curd diameter, total plant weight and leaf weight. Similar results were reported by Quamruzzaman *et al.* (2007) and Gaur *et al.* (1978).

5.1.1.7 Cooking quality by recording sensory attributes:

Sensory quality of vegetables has received more attention in recent years as a need to secure and extend the shares of increasingly competitive markets for fresh produce (Kuchenbuch *et al.* 1999). Panelists scored the overall desirability of samples and their acceptability based on flavour, aroma, texture, and colour. Linear scales were also used to quantitatively describe flavour and texture components (hot, sweet, bitter, crisp) relative to a known reference which was also included as a sample. Panelists detected distinct quality differences among the cultivars. Yano *et al.* (1990) has also employed a 5 point hedonic scale to quantify the acceptability of shredded sample from five fresh cabbage cultivars with regards to appearance, colour, juiciness, firmness, taste and overall desirability.

5.1.1.7.1 Cabbage

Colour, one of the most important sensory attributes that determine food quality is highly affected by light (Hutchings, 1999). In the genotype TSP significant variation was observed for the sensory attribute colour between the produce from hills and plains. Higher score for colour was recorded for the produce from the plains. The mean score of taste was higher in cabbage genotype when grown in plains. Yano *et al.* (1987) reported that plains grown genotypes

Fig. 3 Variation in organoleptic qualities between produce from hills and plains in cabbage

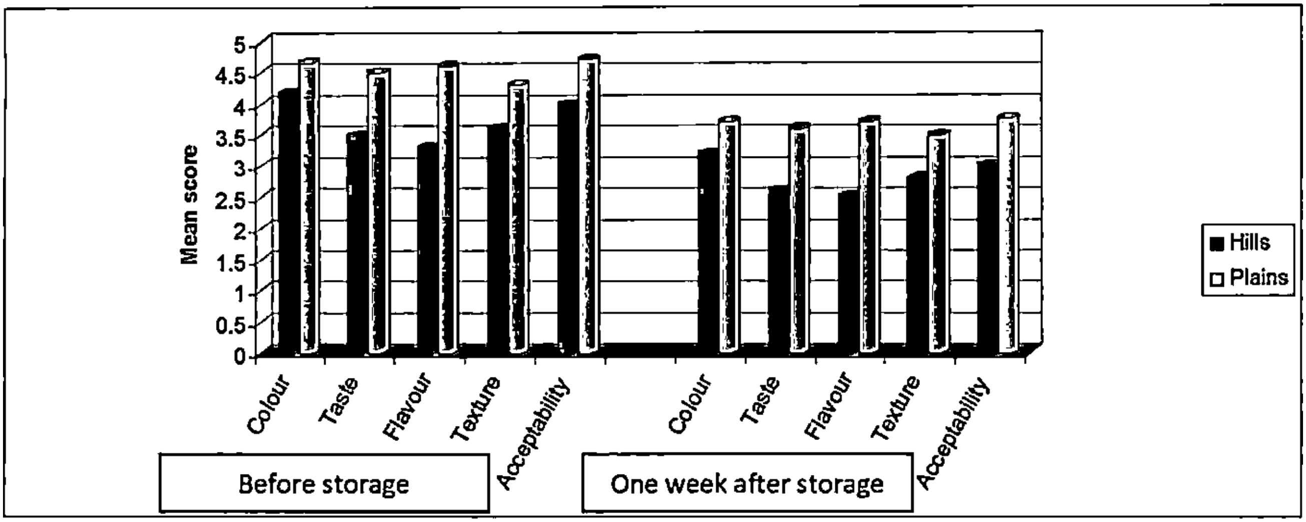


Fig. 3a Genotype Tropical Sun Plus

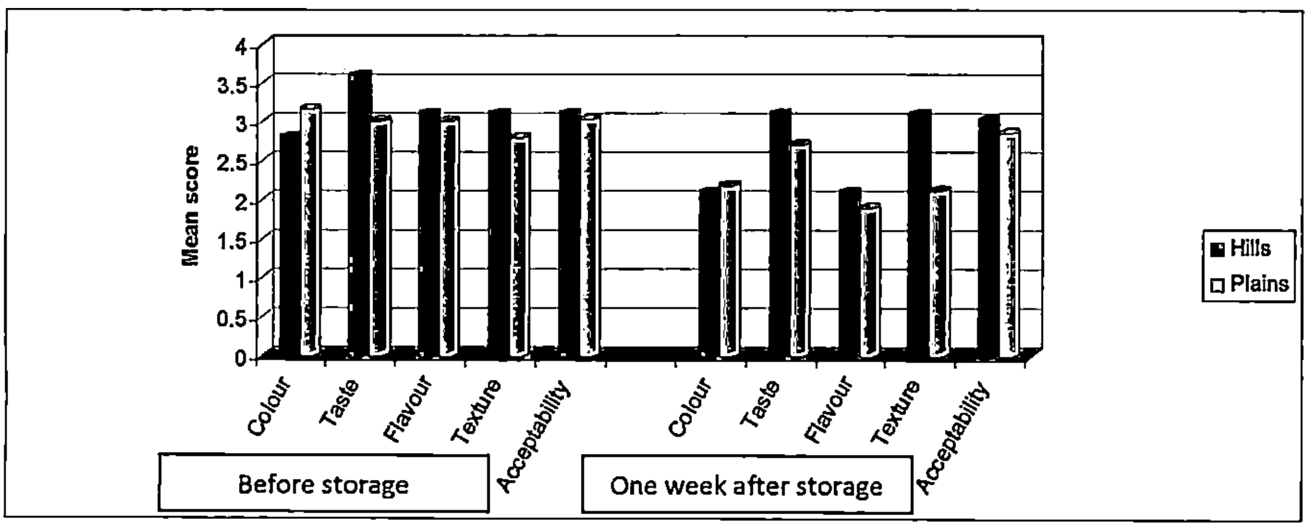


Fig. 3b Genotype NS 183

contain more sugar content than hills because of high concentrations of sulfur containing glucosinolates which influence the perception of sweetness. However in the case of genotype NS 183 higher score for taste was obtained from hills, but the difference was not significant (Fig 3b).

Significant difference was obtained in case of flavour between produce from hills and plains in the genotype TSP. The cabbage genotype NS 183 recorded comparatively lower values for flavour than TSP. The variety, plant spacing and planting date affect a wide range of organic compounds associated with cabbage flavour. This is in agreement with the findings of Macleod and Nussbaum (1977). It is clear that flavour may differ between cabbage varieties and that flavor has a strong effect on sensory quality (Martens, 1985). Similar kinds of observation were also reported by Rosa *et al.* (2001). Similarly, Radovich *et al.* (2003) reported that the planting date has an influence on individual flavour components.

Highest mean score for texture was observed in plains for genotype TSP which may be due to better dry matter and sugar accumulation resulting in better texture in plains as reported by Suojala (2003). Buike and Alsina (2003) suggested that calcium is one of the most important nutrient responsible for improving the sensory quality of cabbage texture. According to Lopez *et al.* (1998) appearance is taken as an indication of freshness, palatability and nutritional value of cabbage. The cabbage genotype TSP recorded superior organoleptic qualities (colour, taste, flavour, texture and overall acceptability) when grown in plains than in hilly region (Fig 3a). However in the case of genotype NS 183, the differences in sensory qualities between produce from hills and plains were not significant. Thakur (2006) has reported that environment over the years was found to significantly influence the sensory quality of produce.

5.1.1.7.2 Cauliflower

In case of cauliflower, variation in the sensory attributes (colour, taste, flavour, texture and overall acceptability) between the produce obtained from hills

Fig. 4 Variation in organoleptic qualities between produce from hills and plains in cauliflower

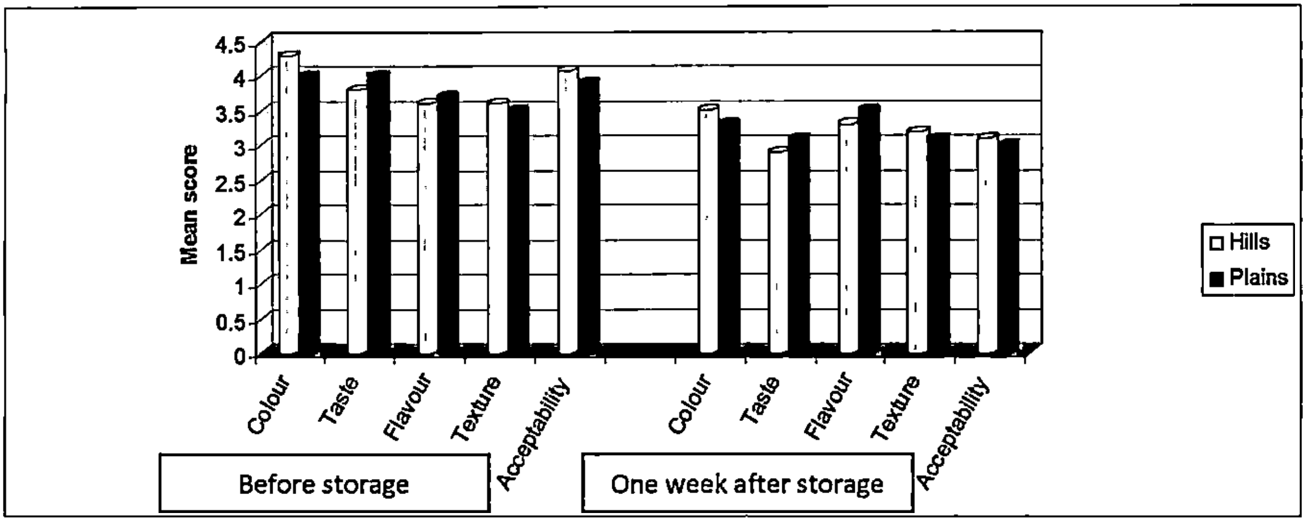


Fig. 4a Genotype NS 60N

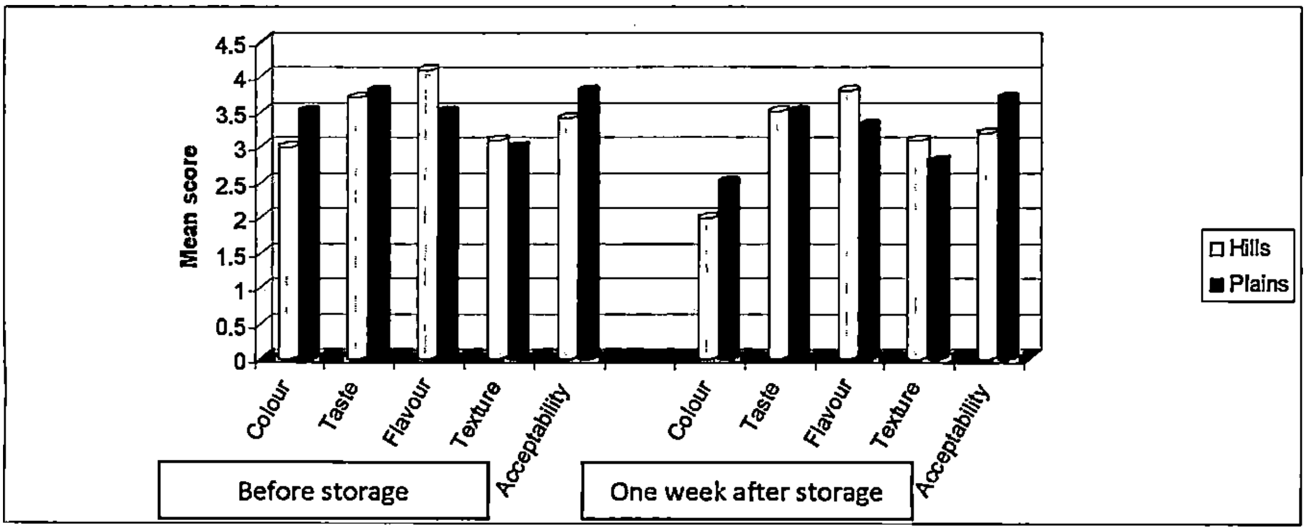


Fig. 4b Genotype NS 133

and plains were not significant in both the genotypes (NS 60N and NS 133). Sensory attributes of cabbage and cauliflower showed decreasing trend when stored for one week (Fig 4a & 4b). Anaerobic metabolism occuring in internal atmospheres of refrigeration will have an adverse effect on the sensory qualities of the product (Ballantyne *et al.*, 1988). So it can be concluded that storage for one week can result in a slight reduction in overall sensory qualities when compared to fresh cabbage and cauliflower. Similar finding was also observed by Fenwick *et al.* (1990).

The result of the sensory evaluation studies in cabbage revealed that sensory qualities were improved in cabbage genotype TSP when raised in plains. Significant variation in organoleptic qualities between produce from hills and plains both in case of cabbage and cauliflower was not observed. Suggesting that there was no marked changes in sensory quality when a conventional cool season crop was shifted to nonconventional areas (plains characterized by warm and humid condition).

5.1.2 Biochemical characters

Significant variation was observed in moisture content between the two genotypes. The genotype TSP recorded higher moisture content (90.59 %) than genotype NS 183. In cauliflower no significant difference was observed in case of moisture content between genotypes NS 133 and NS 60N.

Cabbage genotype NS 183 recorded higher acidity content than TSP. Haque *et al.* (2005) suggested that titratable acidity of cabbage depends on the time of planting, cultivars and location. In cauliflower no significant difference was observed in case of acidity between genotypes NS 133 and NS 60N.

A significantly higher content of ascorbic acid was observed in cabbage genotype NS 183 (51.8 mg/ 100g) compared to TSP (12.92 mg/ 100g). Martinez *et al.* (2010) suggested that ascorbic acid content varied according to the cultivars. Similar kinds of observations were also reported by Kadam *et al.* (2008) and

Abusalem (2007). There was significant reduction in ascorbic acid content in cabbage during storage. After one week of storage the ascorbic acid content was 37.67 mg/ 100g and 9.17 mg/ 100g in genotypes NS 183 and TSP respectively.

Lee and Kader (2000) and Podsedek (2007) reported that ascorbic acid is very sensitive to storage condition and it varied depending on temperature, humidity, oxygen and carbon dioxide content. Similarly, Opatova *et al.* (2003) suggested that retention of ascorbic acid varied from 50 to 70% and the losses increased with storage duration.

Before storage ascorbic acid content was comparatively high in cauliflower genotype NS 133 (38.85 mg/ 100g) when compared to NS 60N (8.65 mg/ 100g). A decline in ascorbic acid content after storage was observed in both genotypes NS 133 (19.15 mg/ 100g) and NS 60N (6.91 mg/ 100g). Podsedek (2007) reported that ascorbic acid content in broccoli has shown a decrease up to 70% depending on storage duration, temperature and packaging. Similarly, Favell (1998) suggested that nearly 40% of ascorbic acid was lost during the first 3 days of storage in green bean and further showed a decreasing trend.

Significant variation was observed in protein content between genotype NS 183 (0.73 g/ 100g) and TSP (0.65 g/ 100g). Cabbage genotype NS 183 recorded higher protein content than TSP. Srisangnam *et al.* (2007) opined that higher leaf protein content may due to more favorable climate condition particularly rainfall and better irrigation or due to the residual effect of soil nutrients from previous growing season. In case of cauliflower, genotype NS 133 recorded higher protein content (0.89 g/ 100g) than NS 60N (0.82 g/ 100g).

Phosphorus content was comparatively high in cabbage genotype NS 183 (26 mg/ 100g). Phosphorus content was comparatively high in cauliflower genotype NS 60N (21 mg/100g) than NS 133 (11 mg/ 100g). Cabbage genotype TSP recorded higher calcium content (110 mg/100g) than NS 183 (42 mg/100g). In case of cauliflower, genotype NS 60N recorded a higher calcium content than NS 133. In cabbage no significant difference was observed in case of potassium content between genotypes NS 133 and NS 60N. Relatively high potassium content was observed in cauliflower, genotype NS 133 (320 mg/100g) than NS 60N (253 mg/100g). Similar kinds of observation were also noticed by Watt and Wood (1963).

The cabbage genotype NS 183 was found to superior in nutritive value with higher content of vitamin C and minerals like phosphorus and potassium (Fig 5). In case of cauliflower, genotype NS 133 was found to be nutritionally superior than NS 60N in terms of higher vitamin C, protein and minerals like calcium and potassium (Fig 6).

5.2 Evaluation of storage qualities:

5.2.1 Whole produce

The storage life of cabbage and cauliflower depend mainly on cultivar and growing condition. For best storage results, cabbage should be harvested in a slightly immature stage. Such heads will retain their green color for a longer period of time in storage than fully matured cabbage. The best results are obtained where a temperature of 0°C (32°F) can be maintained in storage studies. It is much easier to maintain both the temperature and relative humidity at the optimum level in refrigerated storages than in common or unrefrigerated storages. In this study whole produce was taken into consideration for evaluation of storage quality.

Colour degradation in cabbage was observed during storage at ambient condition as well as in refrigerator at 4 to 6°C temperature. This may due to degradation of chlorophyll brought about by the activity of enzymes (Dong *et al.*, 2004). Colour was retained during storage at 0 to -1° C as the enzymes responsible for colour degradation are inactive at very low storage temperature. Early incidence of blackening was observed in cabbage and cauliflower stored at ambient condition. According to Jongnam *et al.* (2007) there is a positive relationship between blackening index and polyphenol oxidase activity.

Fig. 7 Effect of packaging and storage conditions on shelf life of cabbage

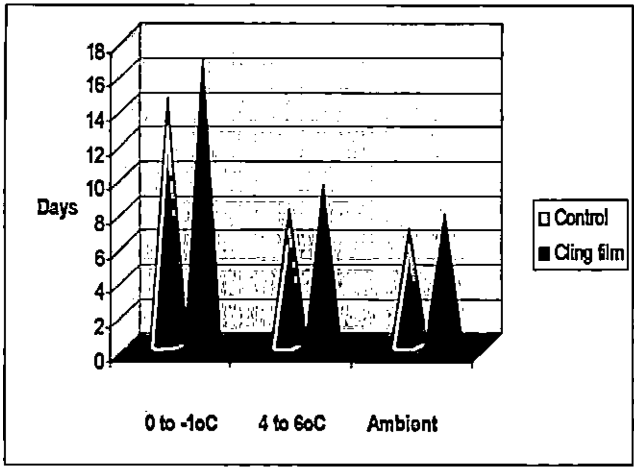


Fig. 7a Genotype NS 183

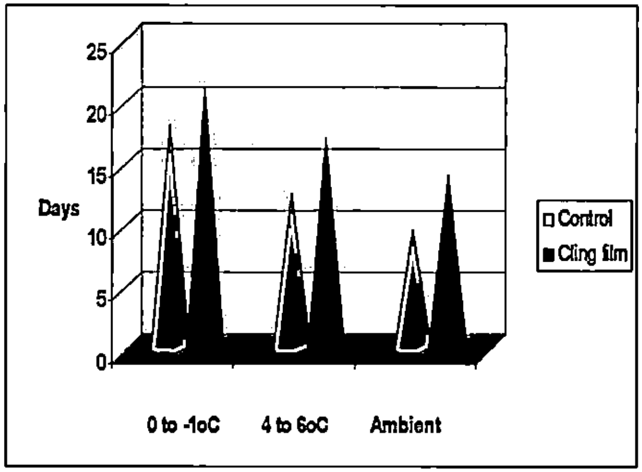


Fig. 7b Genotype Tropical Sun Plus

Fig. 8 Effect of packaging and storage conditions on PLW% of cabbage

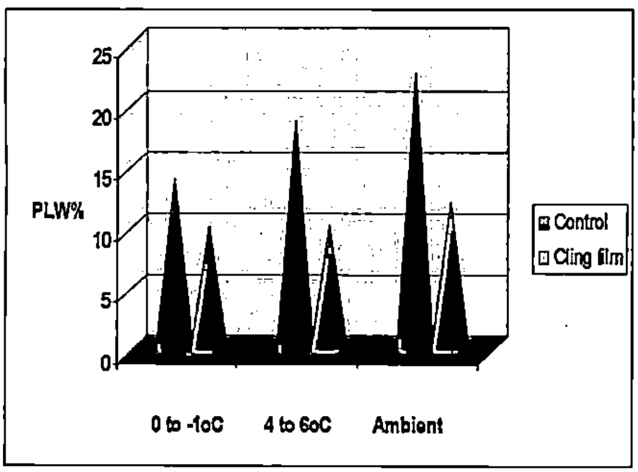


Fig. 8a Genotype NS 183

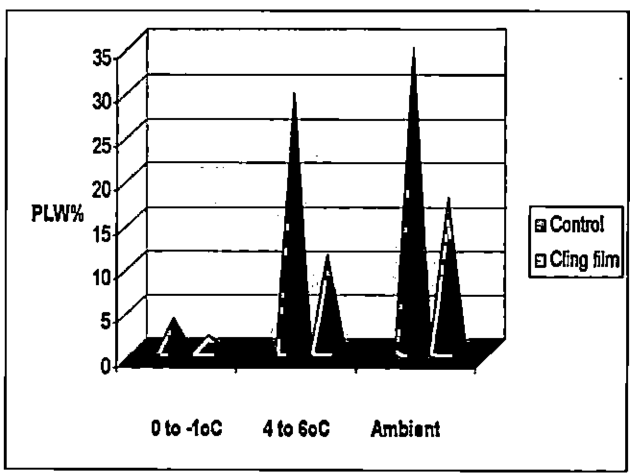


Fig. 8b Genotype Tropical Sun Plus

5.2.1.1 Whole cabbage

Physiological loss in weight (PLW %) was comparatively higher in non packaged produce stored under ambient condition than at 0 to -1° C and 4 to 6°C. Wrapping the produce with cling film and storage at 0 to -1° C resulted in lesser PLW (%) in the genotype NS 183 and TSP (Fig 8). The rate of physiological processes like respiration and transpiration will be slower at lower temperature.

The longest shelf life (16.75 days) was obtained in cling film package (NS 183) under 0 to -1°C temperature regime. In case of TSP, longest shelf life (22 days) was obtained in cling film package under storage at the same temperature (Fig 7). Least shelf life was recorded in non packaged produce, when stored in ambient condition. This is in agreement with the observations of Pritchard and Becker (1989) who reported that storage life depends on cultivar (eg., early maturing cultivars tend to have shorter storage life than late maturing cultivars), quality (eg., freedom from decay) and storage conditions.

5.2.1.2 Whole cauliflower

In cauliflower genotype NS 133 and NS 60N, physiological loss in weight (%) was least in cling film packaged produce stored at 0 to -1° C (Fig 10). In both the genotypes PLW (%) was highest under ambient storage and percentage of PLW was found to decrease with decrease in storage temperature. Berg (1987) reported that increasing RH from 98 to 100% at 0- 1°C can further reduce weight loss and maintain turgidity of the curds as well as free water accumulation on the curds. This is in consonance with the observations of Prange and Lidster (1991).

Longest shelf life in both genotypes (16 and 22.5 days in NS 133 and NS 60N respectively) was obtained in cling film package stored at 0 to -1° C (Fig 9). Storage temperature plays a critical role in determining the rate of deterioration, moisture loss and keeping quality. A similar kind of observation was also reported by Berg (1987).

Fig. 9 Effect of packaging and storage conditions on shelf life of cauliflower

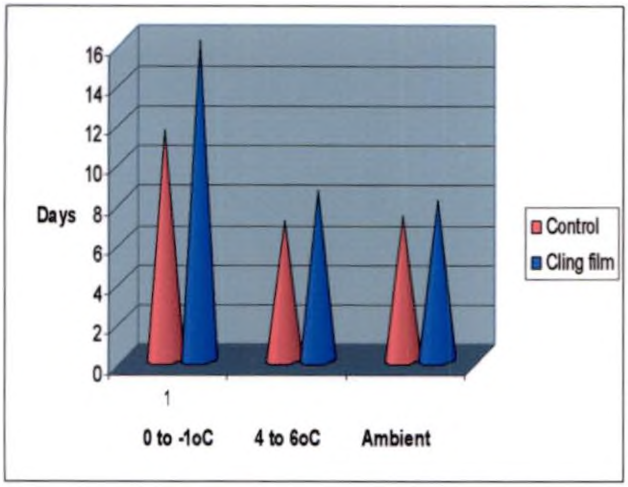


Fig. 9a Genotype NS 133

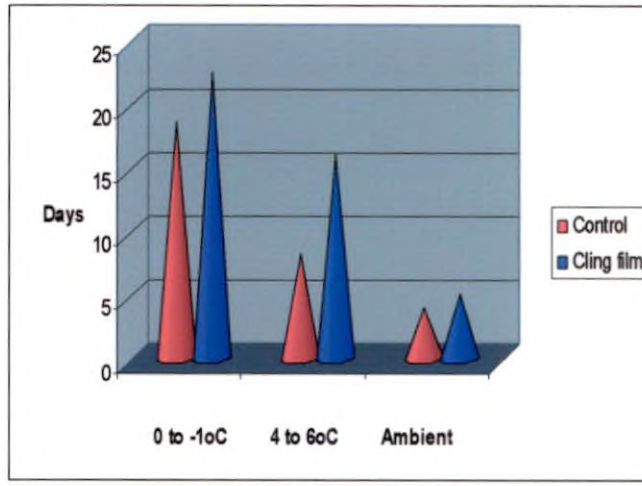


Fig. 9b Genotype NS 60N

Fig. 10 Effect of packaging and storage conditions on PLW% of cauliflower

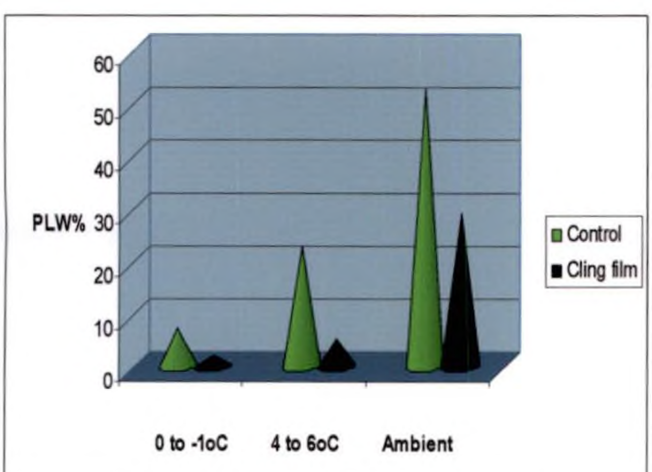


Fig. 10a Genotype NS 133

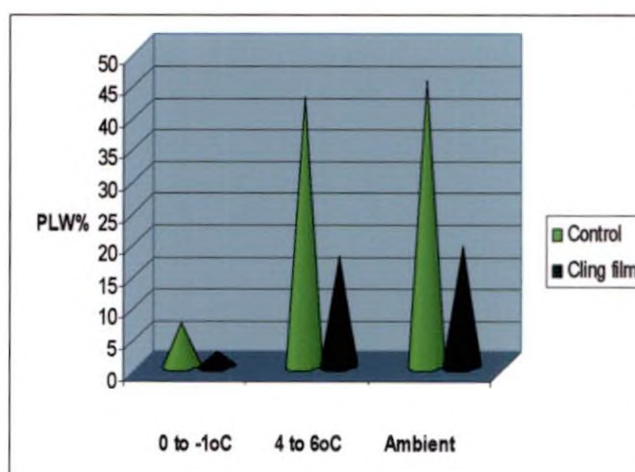


Fig. 10b Genotype NS 60N

5.2.2 Minimally processed produce

Minimally processed (MP) or fresh cut vegetables are ready to eat vegetables which include fresh, washed and chopped vegetables, ready for use and packaged in sealed polymeric films or trays. Minimally processed fruits and vegetables offer a number of advantages such as convenience, time saving and reduction in accumulation of waste. Minimally processed products retain their flavour, aroma and nutrition better than conventionally processed vegetables. Hence there is a growing demand for minimally processed products. Fresh cut cabbage and cauliflower deteriorate faster than intact products, this is due to the wounding associated with processing, which leads to a number of physical and physiological changes affecting the shelf life and quality of the produce. Minimal processing generally increases the rate of metabolic processes that cause deterioration of fresh products. The physical changes or wounding caused by preparation, increase respiration and ethylene production and associated increase occur in rates of other biochemical reactions responsible for changes in colour, flavour, texture and nutritional quality.

5.2.2.1 Prestorage treatments

Minimally processing operation in cabbage involved shredding and in cauliflower involved separation into individual florets. The florets and shredded pieces were subjected to a prestorage treatment of immersion in two per cent warm salt (Nacl) water for 10 minutes.

Blanched cauliflower and cabbage had longer shelf life and visual quality when compared to unblanched because of reduction in the activity of enzyme (polyphenol oxidase) due to blanching. Ions derived from Nacl inhibit PPO. The inhibition of PPO by Nacl had been reported by Lopez (2002). They believed that the inhibition of PPO by Nacl is due to formation of a complex between the halide ion and copper in the enzyme. This is in consonance with the observations of Zawistowski *et al.* (1991).

5.2.2.2 Packaging and storage studies

The atmosphere surrounding minimally processed cabbage and cauliflower is extremely important to extend their shelf life and one of the most influential factors on its composition is the permeability of the film used in packaging. Thus for a given product of known weight and storage temperature, proper film selection is essential for maintaining quality and restricting microbial growth. The films used for packaging of shredded cabbage and cauliflower were selected according to their oxygen transmission rate, water vapour transmission rate in order to prevent the product dehydration. Overall visual quality determined the end of the shelf life from the sensorial point of view. According to Escalona and Aretes (2003) the permeability of packaging material to O_2 and CO_2 determines the degree of deterioration of cut samples.

In cabbage yellowish discolouration, decay and disorder were observed on second day of storage when minimally processed cabbage was packed in high density polyethylene, aluminum tray over wrapped with cling film package and polypropylene and stored at temperature regimes of 4 to 6°C and at ambient condition. Zhuang *et al.* (1995) stated that cabbage contain free radical that would cause the yellowing problem, ethylene synthesis and senescence. Whereas in cauliflower brown spot, brownish discolouration, decay and disorder were observed at second day of storage, in all the packaging material stored at temperature of 4 to 6°C and at ambient condition. According to Dhindsa *et al.* (1981) light has a major influence in colour changes of cauliflower. Similar kind of observation was observed by Sakasim and Kasim (2007). According to Whitakar (1995) browning occurs in cauliflower when phenol and other substrates (eg: anthocyanin) are oxidized, such relations are catalyzed by enzymes such as poly phenol oxidase (PPO) or peroxidase. Similarly, Escalona and Aretes (2003) reported that the browning process was accelerated in unpackaged samples under ambient condition, because of free access to oxygen in the atmosphere.

Fig. 11 Effect of packaging and storage conditions on shelf life of fresh cut cabbage

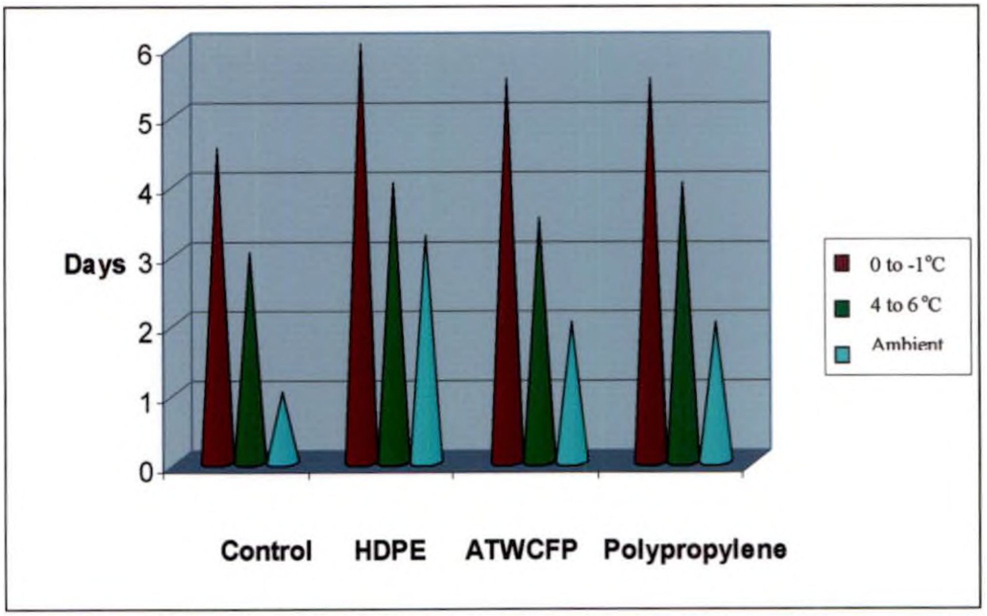


Fig. 11a Genotype NS 183

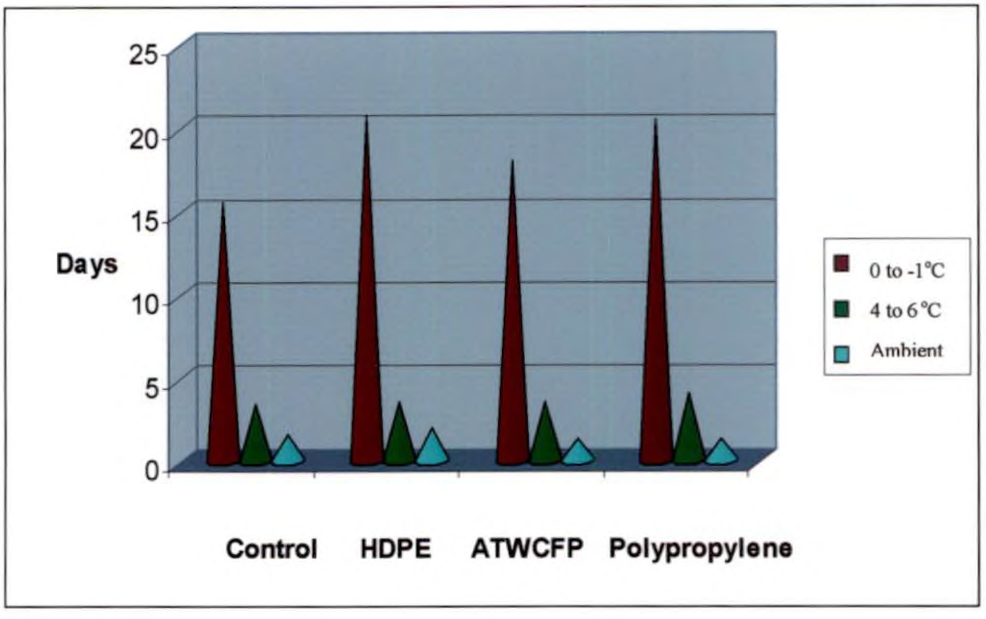


Fig. 11b Genotype Tropical Sun Plus

HDPE – High Density Polyethylene

ATWCFP – Aluminum Tray Over Wrapped with Cling Film Package

5.2.2.2.1 Cabbage

Accelerated weight loss is a major problem with fresh shredded cabbage. Excessive water loss and increased respiration is the major reason for physiological loss in weight. It may due to combined effect of shredding of cabbage and direct effect of room temperature. Any reduction of water vapour pressure in the atmosphere below that in the tissues result in faster water loss ultimately resulting in weight loss (Gaffeny *et al.*, 1985). In whole organs the water in the intracellular space is not directly exposed to the outside atmosphere. However shredding the cabbage exposes the hydrated interior tissues and drastically increases the rate of evaporation of water, which resulted in weight loss of the cut cabbage. Percentage of weight loss was less in produce packaged in high density polyethylene and stored at ambient temperature. According to Singh & Goswami (2006) HDPE is a chemically high permeable polymeric film, as it allows low gas exchange into internal environmental and decrease the PLW (%) of the produce. No physiological loss in weight was observed one week after storage when minimally processed cabbage (TSP and NS 183) was packed in high density polyethylene, aluminum tray over wrapped with cling film and polypropylene and stored at temperature regimes of 0 to -1°C and 4 to 6°C.

According to Varoquax and Wiley (1994) the respiration rate of minimally processed cabbage is generally from a few to over 100 percent higher than the intact produce. Shredded cabbage has a large cut surface. Moreover, cutting of cabbage drastically increases the water evaporation rate which is in agreement with the findings of Brecht (1995).

Significantly longer shelf life was obtained when stored at a temperature regime of 0-1°C with all the treatments (Fig 11). Hu *et al.* (2007) claimed that in cabbage better shelf life could be obtained with low temperature storage regardless of thickness of film or cutting mode. But the longest shelf life (20.75 days) in the genotype TSP was obtained when stored under 0-1°C in HDPE cover. Packaging minimal processed products in unventilated HDPE bags, both under ambient condition and refrigerated storage was superior to other treatments

(Gorny, 2003). According to Elisabete *et al.* (2004) the minimally processed cabbage retained the sensory qualities up to 20 days of storage at 1°C and 5°C in the packaging materials of high O_2 permeability like HDPE. According to Lana (2000) minimally processing of cabbage induced stress and undesirable metabolic changes that reduced the product shelf life in relation to that of intact vegetables. The metabolic changes include increase in respiration and transpiration rates, pathological breakdown, synthesis of secondary compounds and membrane lipid breakdown.

The shelf life was found to be more at low temperature storage than at ambient storage under the same treatment. This is because the relative humidity under refrigerated conditions is higher compared to ambient conditions hence the vapour pressure is reduced, resulting in lower rate of moisture loss from the commodity. Besides, lower temperature would have reduced the rate of respiration and hence the relative increase in the shelf life.

5.2.2.2.2 Cauliflower

Significant weight loss during storage was observed in all the packaging material irrespective of treatments. Weight loss was due to evaporation of water from the surface of fresh cut cauliflower. Percentage of physiological loss in weight was less (genotype NS 133) in all the three packaging materials when stored at ambient temperature than the control. Whereas in genotype NS 60N, PLW (%) was comparatively less in high density polyethylene when stored at ambient temperature. According to Singh & Goswami (2006) HDPE is a chemically high permeable polymeric film, as it allows low gas exchange into internal environmental and increase the shelf life of the produce.

Zhou *et al.* (2004) reported that rapid loss of weight is due to the influence of minimal processing unit operations such as cutting, shredding etc. Low temperature of 0 to -1°C in the storage environment was found to reduce the physiological loss in weight. According to Dong *et al.* (2004) evaporation loss of water from stored material is the most obvious way in which freshness is lost and

Fig. 12 Effect of packaging and storage conditions on shelf life of fresh cut cauliflower

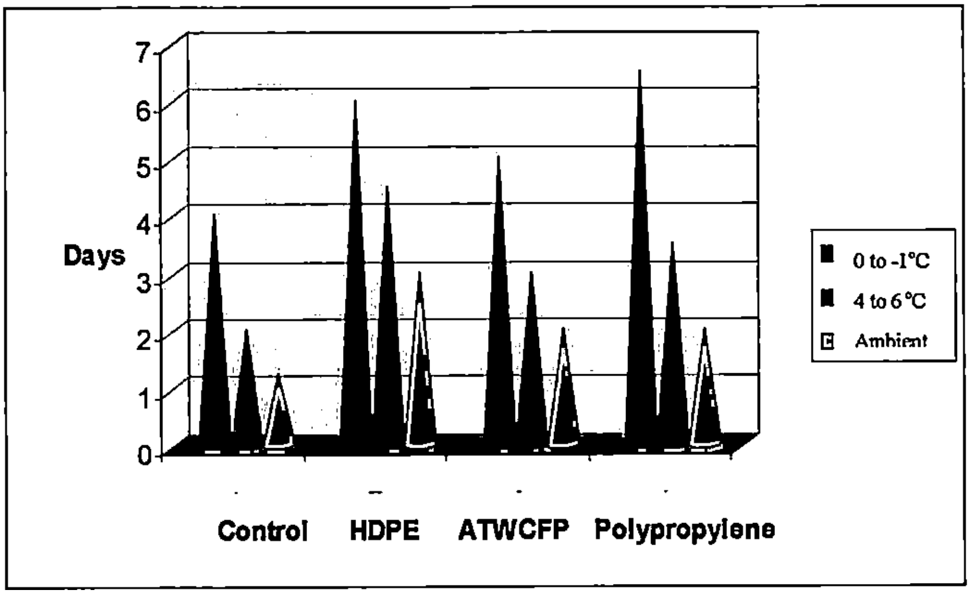


Fig. 12a Genotype NS 133

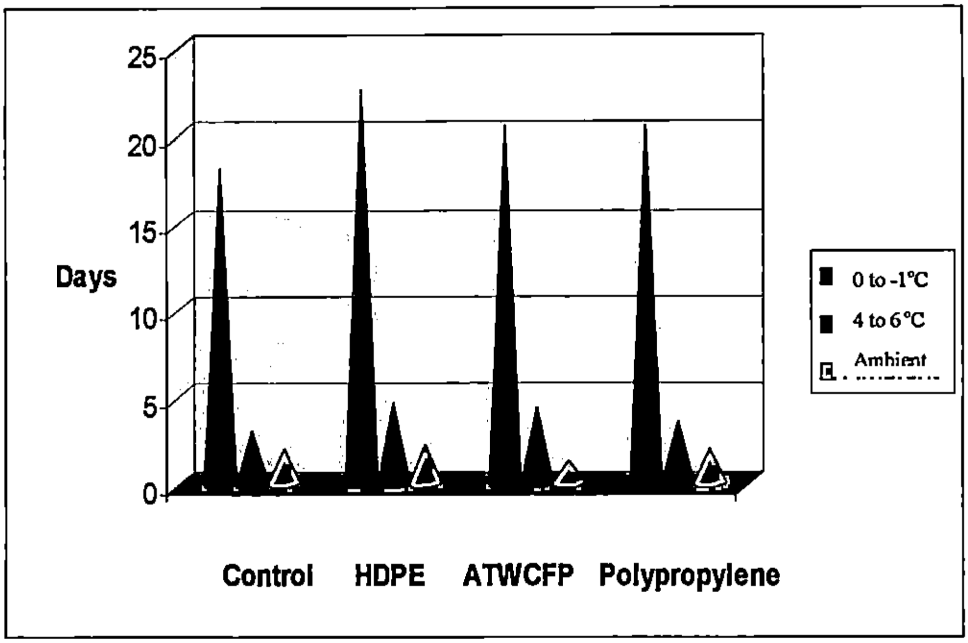


Fig. 12b Genotype NS 60N

HDPE – High Density Polyethylene

ATWCFP – Aluminum Tray Over Wrapped with Cling Film Package it affects the appearance, texture and stability under ambient conditions. Relatively high temperature experienced under ambient conditions could have accelerated the physiological processes like respiration and transpiration leading to increased weight loss.

The deterioration in physical attributes (colour and firmness) is the main factor that limits the shelf life of fresh cut cauliflower (Schlimme, 1995). A longer shelf life of 22.5 days were obtained in HDPE packaging and storage at 0 to -1°C in the genotype NS 60N (Fig 12b). Similar kind of observation was reported by Carlin *et al.* (1990). The result is in conformity with the findings of Dhall *et al.* (2010) who observed that cauliflower curds individually packed in high density polyethylene bags (20μm) with perforation (6 holes/bag) can be stored up to 21 days at 0 ± 1°C and 90–95% RH and it resulted maximum retention of white colour of curd and minimum spoilage.

In the genotype NS 133, no significant difference was noticed in shelf life between all the packaging materials stored at 0 to -1°C (Fig 12a). Least shelf life was recorded in control stored at ambient condition. Madalena (2009) suggested that stability of fresh cut cabbage was higher at the temperature of 1- 5 °C compared to those stored in the ambient temperature.

Minimally processed cabbage and cauliflower are perishable and demonstrate fast degradation of quality when stored at inadequate temperatures as a consequence of damage caused to tissue during cutting, shredding and packaging. Operation involved in conditioning cabbage as minimally fresh processed products generally increase its deterioration and hence it is essential that all fresh cut items should be kept at the lower temperature feasible through out the cold chain, and the range of 0°C to 5°C is strongly recommended for keeping quality and extending shelf life. (Huxsoll *et al.*, 1989: Varoquax and Wiley, 1994).

Summary

6. SUMMARY

The study on "Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude" was undertaken at the Department of Processing Technology, College of Horticulture, during 2009-11. The study was undertaken with the objective of evaluating the postharvest quality attributes and shelf life of cabbage and cauliflower grown in plains and high altitudes.

Four genotypes each in cabbage (NS183, NS160, NS 35 and Tropical Sun Plus) and cauliflower (NS 60 N, NS133, Pusa Meghna and Basant) were evaluated both in hills and plains for yield and postharvest quality attributes.

Cabbage genotypes took longer time (30 -33 days) to reach harvest maturity in plains than hilly region. Significant differences were observed in yield of cabbage which ranged from 22.6 – 29.3 Kg /16m^2 in hills and 1.27 – 22.06 Kg /16m^2 in plains. The cabbage genotype NS 183 recorded earliness (100.80 days) and highest head yield (29.3 Kg /16^{2}m) in hilly region. However in plains Tropical Sun Plus recorded the highest yield (22.06 Kg /16^{2}m) among the different genotypes evaluated.

Significant variation with respect to head weight was observed among the different regions. The head weight ranged from 610.4 – 816.8 g in hilly region and 46.96 – 729.6 g in plains. Highest head weight was recorded in cabbage genotype NS 183 (816.8 g) in the hilly region and Tropical Sun Plus (729.6 g) in the plains.

Significant differences were observed in head height which ranged from 12.23 - 14.96 cm in hilly region and 7.97 – 11.1 cm in plains. The cabbage genotype NS 183 registered highest value for head height in hilly region (14.96 cm) and Tropical Sun Plus in the plains (11.1 cm).

In cauliflower harvest maturity was delayed by 39 – 45 days in plains. Earliness was observed in cauliflower genotype NS 60N (83.88 days) in hilly region and genotype Pusa Meghna in the plains (128.16 days).

The variation observed in the yield of cauliflower genotypes was significant and it ranged from 21 – 26.4 Kg /16 m^2 in hills and 0.78 – 1.43 Kg /16 m^2 in plains. Among the cauliflower genotypes grown in hilly region NS 133 recorded the highest curd yield (26.4 Kg /16 m^2). In plains, the yield was very less for all the genotypes.

The curd weight of cauliflower genotypes differed significantly and it ranged from 610 – 800g in hills. NS 133 recorded the highest curd weight (800 g) in hilly region. In plains, curd weight was very less for all the genotypes but significant difference was noticed between the genotypes.

Curd height ranged from 12.32 to 13.93 cm in hills and 6.37 – 8.15cm in plains and the differences were significant. The highest curd height was recorded for cauliflower genotype NS 133 (13.93 cm) when grown in hilly region. NS 60N recorded more height (8.15 cm) compared to all the other genotypes raised in plains.

In hilly region, cauliflower genotypes NS 133, Basant, NS 60 N and Pusa Meghna produced firm and uniform curds but in plains curds were thicker and non uniform. In the case of cabbage no significant difference was noticed in terms of head solidity for both the regions.

Browning was noticed in the cabbage, genotypes NS 160 and NS 35 when grown in both regions. NS 35 exhibited whiptail symptoms when raised in plains. NS 60N raised in hilly region exhibited looseness of curd and flower stalk emergence. Incidence of black or brown specks was the serious problem observed in all the cauliflower genotypes when grown in plains.

The results obtained in the present study revealed that in cabbage, NS 183 is the best performing genotype in high altitude region and Tropical Sun Plus in the plains in terms of high head yield, head weight, head height, head solidity, early maturity and better adaptivity. Among the cauliflower genotypes, NS133 was found to be the best in high altitude region and NS 60N in the plains with respect to high curd yield, curd weight, curd height and curd solidity.

The cabbage and cauliflower genotypes which exhibited superior performance in hills and plains were selected for further sensory, biochemical and storage studies. Cooking quality of cabbage and cauliflower genotypes was evaluated by organoleptic method. Scores obtained for different sensory qualities of cabbage genotype Tropical Sun Plus was found to be statistically significant between the regions. The highest mean score for colour (4.66), taste (4.5), texture (4.3), flavour (4.6) and overall acceptability (4.75) was recorded for cabbage grown in the plains. In the case of cauliflower, no significant difference was noticed in terms of sensory quality for both the regions.

The biochemical constituents (moisture, acidity, ascorbic acid, protein and minerals) of the best performing genotypes identified both from hills and plains in cabbage and cauliflower were analysed. The cabbage genotype NS 183 recorded comparatively higher values for biochemical constituents like acidity (0.144%), ascorbic acid (51.8 mg/100g), protein (0.73 g/100g), phosphorus (26 mg/100g) and potassium (200 mg/100g). Significant variation was noticed in biochemical constituents between the cauliflower genotypes and higher values were recorded in NS 133 for acidity (0.119%), ascorbic acid (38.85 mg/100g), protein (0.89 g/100g) and potassium (320 mg/100g).

The whole cabbage and cauliflower were wrapped with cling film and stored under three different temperature regimes (0 to -1°C, 4 to 6°C and ambient condition). Physiological loss in weight (PLW %) was comparatively higher in cabbage and cauliflower stored under ambient condition than at 0 to -1°C and 4 to 6°C. Whole cabbage and cauliflower wrapped with cling film and stored at 0 to -1° C recorded less PLW% in one week after storage. Longest shelf life in cabbage genotypes Tropical Sun Plus (21 days) and NS 183 (16.75 days) was obtained in cling film packaged material, stored at 0 to -1° C. Wrapping the whole cauliflower with cling film followed by storage at 0 to -1°C extended shelf life of NS 133 (16 days) and NS 60N (22.5 days).

Colour deterioration, decay and disorder were less when stored at 0 to -1°C in cabbage and cauliflower. PLW% was highest and shelf life was shortest under ambient condition in unpackaged produce of cabbage and cauliflower

The influence of packaging material (high density polyethylene, semi rigid metallised aluminum tray over wrapped with cling film and polypropylene) and storage conditions (0 to -1°C, 4 to 6°C and ambient) on minimally processed produce of cabbage and cauliflower were evaluated. The shelf life was significantly extended in HDPE packaged produce stored at a temperature regime of 0 to -1°C in cabbage genotype Tropical Sun Plus (20.75 days) and cauliflower genotype NS 60N (22.5 days).

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Appendix

APPENDIX - I

Units

^{o}C = Centigrade

RH = Relative humidity

% = Per cent

mm = Mille meter

cm = Centimeter

hac = Hectare

kg ha^{-1} = Kilogram per hectare

ppm= Parts per million

ml= Mille litre

nm= Nano meter

Abbreviations

GA= Gibberellic Acid

NAA = Naphthalene Acetic Acid

FYM = Farm Yard Manure

RDF = Recommended dose of fertilizer

CO_2 = Carbon di Oxide

O_2 = Oxygen

SO_2 = Sulphur di Oxide

PVC = Poly Vinyl Chloride

NaCl = Sodium Chloride

MP = Minimally processed

HDPE = High Density Polyethylene

ATWCF = Aluminum Tray over Wrapped with Cling Film

ARS = Agricultural Research Station

O&V = Orange and Vegetable farm

NS = Namdhari Seeds

TSP = Tropical Sun Plus

NaoH = Sodium Hydroxide

PLW= Physiological loss in weight

APPENDIX - II

ARS, Mannuthy

Weather parameters during October 27 to March 12

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
27/10/2010	28.4	22.9	94.0	30.4
28/10/2010	31.2	21.4	82.5	10.2
29/10/2010	31.0	21.0	81.5	29.4
30/10/2010	30.0	21.8	83.0	73.4
31/11/2010	30.0	21.4	83.5	5.4
1/11/2010	30.1	23.5	85.5	35.5
2/11/2010	30.2	21.5	83.5	0
3/11/2010	31.8	22.3	81.0	0
4/11/2010	31.1	23.8	81.5	4.0
5/11/2010	30.0	23.6	80.5	16.2
6/11/2010	28.4	21.5	84.0	0
7/11/2010	28.2	22.7	88.5	0
8/11/2010	31.8	22.0	76.5	0
9/11/2010	30.9	22.3	82.5	32.9
10/11/2010	32.1	22.5	81.0	66.1
11/11/2010	28.8	21.5	83.0	26.1
12/11/2010	31.4	20.9	80.5	0
13/11/2010	30.6	23.3	84.5	0
14/11/2010	32.6	23.3	75.5	0
15/11/2010	32.7	22.8	73.0	0
16/11/2010	32.7	22.5	79.0	2.8
17/11/2010	30.2	22.5	87.5	30.4
18/11/2010	31.4	22.2	78.0	0
19/11/2010	31.4	23.0	77.0	0
20/11/2010	32.2	22.4	71.0	0

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
21/11/2010	30.0	22.8	82.0	0
22/11/2010	30.0	22.8	81.0	0
23/11/2010	30.3	22.1	79.5	0
24/11/2010	31.0	21.8	93.0	0
25/11/2010	28.9	23.0	87.5	0
26/11/2010	27.8	22.5	78.5	0
27/11/2010	27.5	21.7	81.0	0
28/11/2010	28.8	22.5	87.5	0
29/11/2010	30.0	22.8	71.0	0
30/11/2010	31.2	24.0	63.5	0
1/12/2010	27.9	23.7	81.5	0
2/12/2010	30.7	23.5	75.0	0
3/12/2010	29.3	22.5	88.0	0
4/12/2010	31.0	21.5	75.0	0
5/12/2010	30.6	21.3	65.5	0
6/12/2010	31.9	20.5	74.0	0
7/12/2010	33.2	20.0	69.5	0
8/12/2010	30.6	21.5	79.0	0
9/12/2010	31.4	21.5	74.5	0
10/12/2010	31.2	21.5	80.0	0
11/12/2010	31.2	21.2	81.0	0
12/12/2010	30.8	22.1	76.0	0
13/12/2010	31.9	19.4	73.0	0
14/12/2010	31.6	20.9	72.5	0
15/12/2010	31.9	21.8	79.0	3
16/12/2010	30.4	23.4	73.0	16.6
17/12/2010	30.9	23.0	69.5	0
18/12/2010	30.9	23.7	69.0	0

Date	Maximum temperature (^oC)	Minimum temperature (^oC)	Relative humidity (%)	Rain fall (mm)
19/12/2010	30.5	23.1	58.5	0
20/12/2010	31.1	23.5	66.5	2.4
21/12/2010	30.6	23.2	65.0	0
22/12/2010	31.6	22.2	71.0	0
23/12/2010	30.6	21.2	62.0	0
24/12/2010	30.0	20.7	62.0	0
25/12/2010	30.1	20.4	62.0	0
26/12/2010	31.1	20.5	66.0	0
27/12/2010	31.2	21.3	63.5	0
28/12/2010	31.3	21.7	60.5	0
29/12/2010	30.2	24.2	61.5	0
30/12/2010	31.1	23.3	64.5	0
31/12/2010	31.4	22.3	69.5	0
1/1/2011	32.3	22.7	70.0	0
2/1/2011	31.2	22.5	73.5	0
3/1/2011	31.0	21.1	77.0	0
4/1/2011	32.5	20.7	64.0	0
5/1/2011	31.6	23.1	62.0	0
6/1/2011	32.3	22.5	61.0	0
7/1/2011	33.1	23.7	62.0	0
8/1/2011	32.9	22.7	73.5	0
9/1/2011	33.9	23.3	68.0	0
10/1/2011	33.5	23.8	72.5	0
11/1/2011	33.6	24.0	71.5	0
12/1/2011	33.8	22.1	59.0	0
13/1/2011	34.8	20.5	95.0	0
14/1/2011	32.2	19.8	45.0	0
15/1/2011	32.2	18.2	51.0	0

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
16/1/2011	32.6	18.8	62.0	0
17/1/2011	32.9	22.8	65.0	0
18/1/2011	33.4	22.3	31.5	0
19/1/2011	33.4	21.7	46.5	0
20/1/2011	33.6	18.8	47.5	0
21/1/2011	32.8	19.0	53.0	0
22/1/2011	31.8	21.9	52.5	0
23/1/2011	32.0	21.0	48.0	0
24/1/2011	32.0	23.2	48.5	0
25/1/2011	31.5	22.7	54.5	0
26/1/2011	32.1	23.3	54.0	0
27/1/2011	32.8	24.9	57.0	0
28/1/2011	32.8	23.0	52.5	0
29/1/2011	33.7	22.1	56.0	0
30/1/2011	34.0	23.5	50.5	0
31/1/2011	34.1	24.4	40.0	0
1/2/2011	34.6	23.9	42.0	0
2/2/2011	32.0	22.8	38.5	0
3/2/2011	33.1	23.2	39.5	0
4/2/2011	33.4	20.4	44.0	0
5/2/2011	34.1	18.3	36.5	0
6/2/2011	33.8	21.9	44.0	0
7/2/2011	34.1	19.7	51.0	0
8/2/2011	34.5	22.6	62.0	0
9/2/2011	34.5	22.4	55.0	0
10/2/2011	35.0	21.3	42.5	0
11/2/2011	34.4	20.9	41.0	0
12/2/2011	33.6	23.6	32.5	0
13/2/2011	34.7	20.8	37.0	0

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
14/2/2011	35.0	19.3	50.0	0
15/2/2011	32.7	21.5	62.0	0
16/2/2011	32.9	21.2	65.5	0
17/2/2011	34.0	20.7	72.0	0
18/2/2011	32.9	21.0	69.0	0
19/2/2011	33.7	19.1	71.5	0
20/2/2011	33.6	21.9	75.0	0
21/2/2011	32.4	23.6	72.0	0
22/2/2011	34.7	23.7	71.5	52.6
23/2/2011	33.9	23.1	68.5	5.5
24/2/2011	33.2	23.7	70.5	0.8
25/2/2011	32.9	23.8	67.5	0
26/2/2011	32.6	23.8	74.0	11.6
27/2/2011	33.4	22.6	69.5	0
28/2/2011	33.7	24.2	55.5	0
1/3/2011	33.7	23.3	54.0	0
2/3/2011	34.2	23.1	40.5	0
3/3/2011	35.5	22.8	34.0	0
4/3/2011	35.6	21.3	53.5	0
5/3/2011	34.7	22.9	66.5	0
6/3/2011	36.5	24.1	61.0	0
7/3/2011	36.6	22.3	57.0	0
8/3/2011	37.4	23.3	55.5	0
9/3/2011	35.0	24.3	70.0	0
10/3/2011	34.2	22.9	74.5	0
11/3/2011	34.6	24.1	74.5	0
12/3/2011	36.0	23.7	57.5	5.8

APPENDIX - III

Orange and vegetable farm, Nelliyampathy
Weather parameters during October 23 to February 4

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
23/10/2010	23.0	16.0	81.0	6.4
24/10/2010	23.0	16.0	80.0	0
25/10/2010	24.0	16.0	80.0	0
26/10/2010	26.0	15.0	78.0	0
27/10/2010	24.0	16.0	80.0	0
28/10/2010	24.0	16.0	78.0	36.2
29/10/2010	23.0	16.0	77.0	33.4
30/10/2010	23.0	17.0	78.0	11.4
31/11/2010	23.0	17.0	79.0	25.0
1/11/2010	24.0	18.0	79.0	3
2/11/2010	24.0	17.0	78.0	0
3/11/2010	24.0	17.0	79.0	0
4/11/2010	24.0	17.0	79.0	0
5/11/2010	24.0	17.0	79.0	0
6/11/2010	24.0	17.0	78.0	36.9
7/11/2010	24.0	17.0	74.0	0
8/11/2010	24.0	17.0	79.0	0
9/11/2010	24.0	17.0	78.0	0
10/11/2010	24.0	17.0	80.0	32.0
11/11/2010	25.0	16.0	79.0	3.2
12/11/2010	24.0	16.0	79.0	42.0
13/11/2010	24.0	16.0	79.0	0
14/11/2010	24.0	18.0	79.0	3.2
15/11/2010	25.0	16.0	76.0	0
16/11/2010	24.0	18.0	79.0	8.2
17/11/2010	24.0	17.0	80.0	12.4

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
18/11/2010	24.0	17.0	79.0	45.0
19/11/2010	24.0	18.0	80.0	3.4
20/11/2010	24.0	17.0	78.0	0
21/11/2010	23.0	17.0	78.0	31.4
22/11/2010	23.0	17.0	78.0	3.0
23/11/2010	23.0	17.0	78.0	56.0
24/11/2010	23.0	17.0	76.0	1.6
25/11/2010	23.0	17.0	76.0	4.2
26/11/2010	23.0	17.0	76.0	0
27/11/2010	23.0	17.0	80.0	10.2
28/11/2010	23.0	17.0	80.0	3.0
29/11/2010	23.0	16.0	81.0	6.4
30/11/2010	23.0	16.0	71.0	0
1/12/2010	24.0	17.0	79.0	2.4
2/12/2010	24.0	17.0	80.0	20.6
3/12/2010	24.0	17.0	79.0	11.2
4/12/2010	24.0	17.0	79.0	0
5/12/2010	24.0	17.0	79.0	0
6/12/2010	24.0	18.0	79.0	12.0
7/12/2010	24.0	18.0	79.0	10.2
8/12/2010	24.0	18.0	80.0	10.4
9/12/2010	24.0	18.0	80.0	0
10/12/2010	24.0	18.0	80.0	0
11/12/2010	24.0	16	79.0	0
12/12/2010	24.0	16	78.0	0
13/12/2010	24.0	12	79.0	0
14/12/2010	23.0	14.0	79.0	0
15/12/2010	23.0	14.0	80.0	7.0
16/12/2010	24.0	16.0	80.0	3.0

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
17/12/2010	24.0	17.0	78.0	0
18/12/2010	24.0	17.0	75.0	0
19/12/2010	24.0	17.0	75.0	12.6
20/12/2010	24.0	16.0	73.0	9.1
21/12/2010	27.0	17.0	79.0	0
22/12/2010	22.0	14.0	76.0	0
24/12/2010	23.0	12.0	78.0	0
25/12/2010	24.0	13.0	78.0	0
26/12/2010	24.0	14.0	79.0	0
27/12/2010	24.0	14.0	79.0	0
28/12/2010	24.0	14.0	78.0	0
29/12/2010	24.0	14.0	78.0	0
30/12/2010	23.0	16.0	78.0	0
31/12/2010	23.0	17.0	79.0	0
1/1/2011	24.0	14.0	78.0	0
2/1/2011	24.0	16.0	78.0	0
3/1/2011	24.0	16.0	76.0	0
4/1/2011	24.0	16.0	66.0	0
5/1/2011	24.0	16.0	72.0	0
6/1/2011	25.0	16.0	78.0	0
7/1/2011	24.0	16.0	78.0	0
8/1/2011	24.0	16.0	79.0	0
9/1/2011	24.0	16.0	79.0	0
10/1/2011	24.0	16.0	79.0	0
11/1/2011	21.0	17.0	80.0	0
12/1/2011	23.0	14.0	79.0	0

Date	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
13/1/2011	22.0	12.0	78.0	0
14/1/2011	24.0	13.0	71.0	0
15/1/2011	24.0	13.0	72.0	0
16/1/2011	24.0	14.0	74.0	0
17/1/2011	24.0	14.0	76.0	0
18/1/2011	24.0	14.0	76.0	0
19/1/2011	22.0	14.0	65.0	0
20/1/2011	24.0	15.0	69.0	0
21/1/2011	24.0	14.0	67.0	0
22/1/2011	24.0	14.0	76.0	0
23/1/2011	24.0	14.0	76.0	0
24/1/2011	24.0	15.0	78.0	0
25/1/2011	24.0	14.0	79.0	0
26/1/2011	24.0	14.0	76.0	0
27/1/2011	24.0	14.0	78.0	0
28/1/2011	23.0	15.0	78.0	0
29/1/2011	24.0	14.0	78.0	0
30/1/2011	24.0	14.0	76.0	0
31/1/2011	25.0	14.0	77.0	0
1/2/2011	24.0	14.0	78.0	0
2/2/2011	25.0	14.0	77.0	0
3/2/2011	25.0	16.0	78.0	0
4/2/2011	25.0	15.0	79.0	0

Total =104 days

APPENDIX IV

Score card

Name of the scorer:

Product:

Please score the given products using the following 5 point Hedonic scale

Score	**Inference**
1	Dislike very much
2	Dislike
3	Neither like nor dislike
4	Like
5	Like very much

Product code	Colour	Taste	Flavour	Consistency	Overall acceptance

Remarks: (Please write which flavour is dominating, weather you find the colour appealing.)

Signature:

EVALUATION OF POSTHARVEST QUALITY ATTRIBUTES OF CABBAGE AND CAULIFLOWER GROWN IN PLAINS AND HIGHER ALTITUDE

By

K. ELAVARASAN
(2009-12-118)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Horticulture

(PROCESSING TECHNOLOGY)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Processing Technology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2011

ABSTRACT

The studies on "Evaluation of postharvest quality attributes of cabbage and cauliflower grown in plains and higher altitude" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 2009 - 2011. The study was undertaken with the objective of evaluating the postharvest quality attributes and shelf life of cabbage and cauliflower grown in plains and higher altitude.

The study was conducted at ARS, Mannuthy (plains) and Orange and Vegetable farm, Nelliyampathy (hill station). Four genotypes each in cabbage (NS183, NS160, NS 35 and Tropical Sun Plus) and cauliflower (NS 60 N, NS133, Pusa Meghna and Basant) were evaluated both in plains and higher altitude. Significant differences were observed in yield of cabbage which ranged from 22.6 – 29.3 kg /16m^2 in hills and 1.27 – 22.06 kg /16m^2 in plains. Among the cabbage genotypes, NS 183 was found to be the best for hilly region in earliness, yield and yield attributes. The cabbage genotype Tropical Sun Plus exhibited better performance in plains in terms of high head yield (22.06 Kg /16^{2}m), head weight (729.6 g) and head height (11.1 cm). Harvest maturity was delayed by 39 – 45 days in the plains as compared to higher altitudes.

The cauliflower genotypes NS 60N took lesser days to attain harvest maturity in hills (83.88 days) and Pusa Meghna in the plains (128.16 days). Significant variation was observed in curd yield of cauliflower which ranged from 21 – 26.4 kg /16 m^2 in hills and 0.78 – 1.43 kg /16 m^2 in plains. NS 133 was found to be the best among the cauliflower genotypes in high altitude region as it recorded high curd yield (26.4 Kg /16^{2}m), curd weight (800g), curd height (13.93 cm), curd solidity, early maturity and better adaptability. Cauliflower genotypes NS 60 N, NS133, Pusa Meghna and Basant produced firm and uniform curds in hilly region, but in plains, curds were thicker and non uniform. In the case of cabbage, no significant difference was noticed in terms of head solidity for both the regions.

The cabbage and cauliflower genotypes which exhibited superior performance in hills and plains were selected for further sensory, biochemical and storage studies. The cabbage genotype Tropical Sun Plus recorded superior organoleptic qualities (colour, taste, flavour, texture and overall acceptability) when grown in plains than hilly region. However in the case of genotype NS 183, the differences in sensory qualities between produce from hills and plains were not significant.

The biochemical constituents (moisture, acidity, ascorbic acid, protein and minerals) of the best performing genotypes identified from hills and plains both in cabbage and cauliflower were analysed. The cabbage genotype NS 183 recorded comparatively higher values for biochemical constituents like acidity (0.144%), ascorbic acid (51.8 mg/100g), protein (0.73 g/100g), phosphorus (26 mg/100g) and potassium (200 mg/100g). Significant variation was noticed in biochemical constituents between the cauliflower genotypes and higher values were recorded in NS 133 for acidity (0.119%), ascorbic acid (38.85 mg/100g), protein (0.89 g/100g) and potassium (320 mg/100g).

The whole cabbage and cauliflower were wrapped with cling film and stored under three different temperature regimes (0 to -1°C, 4 to 6°C and ambient condition). Longest shelf life in cabbage genotypes Tropical Sun Plus (21 days) and cauliflower genotype NS 60N (22.5 days) was obtained in cling film pack stored at 0 to -1° C. PLW% was highest and shelf life the shortest under ambient condition in unpackaged produce of cabbage and cauliflower.

The influence of packaging material (high density polyethylene, semi rigid metallised aluminum tray over wrapped with cling film and polypropylene) and storage conditions (0 to -1°C, 4 to 6°C and ambient condition) on minimally processed produce of cabbage and cauliflower were evaluated. The shelf life was significantly extended in HDPE packaged produce stored at 0 to -1°C in cabbage genotype Tropical Sun Plus (20.75 days) and cauliflower genotype NS 60N (22.5 days).