STANDARDIZATION OF PLANTING TIME FOR OFF-SEASON CABBAGE (*Brassica oleracea* L. var. *capitata)* PRODUCTION IN RAIN SHELTER

By

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(2012-12-102)

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THESIS

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Kerala Agricultural University, Thrissur

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DECLARATION

I, **Shanthi Elizabeth Kurian (2012-12-102)**, hereby declare that this thesis entitled **"Standardization of planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata)* production in rain shelter"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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Certified that this thesis, entitled **"Standardization of planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata)* production in rain shelter"** is a bonafide record of research work done independently by **Ms. Shanthi Elizabeth Kurian (2012-12-102)** 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 her.

Dr. P. Indira

Chairman

Advisory Committee

CERTIFICATE

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Shanthi Elizabeth Kurian

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INTRODUCTION

1. INTRODUCTION

Cabbage (*Brassica oleracea* L. var *capitata*) belonging to the family Brassicaceae, is a cool season crop which thrives well in a relatively cool and moist climate. It is the most popular winter vegetable grown throughout India in an area around 3.72 lakh ha with a production of 85.34 lakh tonnes. The average yield of cabbage in India during 2012-2013 was 22.9 MT/ha (NHB, 2014). It is used as salad, boiled vegetable and dehydrated vegetable as well as in cooked curries and pickles. Cabbage is rich in carbohydrates, protein, minerals and vitamins A, B_1, B_2 and C. It is grown extensively in North India for vegetable purpose but to a limited extend in South India, especially Kerala.

Diverse climatic conditions prevailing in Kerala makes the cultivation of different tropical vegetables possible throughout the year in different parts of the state. But the cultivation of cool season vegetables like cabbage and cauliflower was limited to high ranges of Idukki, Wayanad and Palakkad district. Recently with the identification of high yielding tropical hybrids, their cultivation has become possible in the plains also. The ideal season for cultivation is winter (November-January).

During rainy season, high rainfall along with humidity leads to many biotic stresses in vegetables. Scarcity of land also occurs due to water logging thus limiting the vegetable production in Kerala during this season. Hence rainy season (June-September) can be considered as an off-season for most of the vegetables. Under this situation, the only alternative is protected cultivation. Protected cultivation is found beneficial for off-season cultivation of vegetables in the plains and for breaking the seasonal barrier. It is the most profitable farm business giving very high production and income to farmers per unit area of land (Thakur, 1994). Off-season cultivation is a boon of protected cultivation. Though the farmers in North India are taking advantage of this system, farmers of Kerala are not aware at all. Considering these factors, ‘rain shelter’, a low cost naturally ventilated polyhouse was found ideal for

the marginal farmers of Kerala for off-season cultivation. It is made up of locally available materials like bamboo poles, casuarinas poles or M.S. or G. I. pipes covered with UV stabilized sheet of 200 micron thickness.

Farmers involved in the accustomed way of on-season vegetable production are compelled to sell their produce at lower rate since there is often a glut in the market during on-season. Off-season cultivation of vegetables by utilizing low cost protected structures like rain shelters can be considered as a profitable enterprise as these vegetables have good demand and fetch premium price in the market.

Year round supply of vegetables is ensured with an added advantage that the consumers can reduce their dependence on neighbouring states for vegetables which are often loaded with harmful pesticides. Use of hybrids suitable for protected cultivation can augment the production per unit area. By protected cultivation coupled with the use of hybrids, farmers can reap profits from off-season vegetable cultivation.

A study conducted in Kerala Agricultural University revealed that off-season cultivation of cabbage is possible by utilizing rain shelters and among the four hybrids tested, the hybrid NS 43 was found ideal for this purpose. Since yield of cabbage is affected by date of planting, an ideal planting time has to be standardized that would give maximum yield to farmers. Hence the present study was undertaken to standardize the planting time for off-season cabbage production in rain shelter.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Among all vegetables cultivated around the world, cruciferous vegetables occupy a prominent place. Being rich source of dietary nutrients, antioxidants and anti cancerous compounds, their cultivation and use has geared up during the recent years. Tropicalisation of cole crops like cabbage and cauliflower has made it possible to cultivate these crops in the humid tropical areas. The available literature on cultivation of cole crops is reviewed under the following heads.

2.1. Effect of growing conditions on cole crops

2.1.1. Influence of structures and system of cultivation on cole crops

2.1.2. Influence of season/time of cultivation on growth and yield of cole crops

2.2. Cultivars

2.2. Pest and disease incidence

2.3. Economics of cultivation

2.1. EFFECT OF GROWING CONDITIONS ON COLE CROPS

2.1.1. Influence of structures and system of cultivation on cole crops

Kjeldsen (1990) reported that covering chinese cabbage (*Brassica pekinensis*) plants with polypropylene non-woven fibre sheets until harvest resulted in higher head weight along with a crop advancement of one week when compared to the uncovered ones.

The use of floating covers in winter and green houses in summer with shading to reduce light intensity and misting to reduce temperature was studied on Chinese cabbage cultivar Konaeggi in Korea Republic. Shading and misting in green houses lowered air, leaf and soil temperatures compared with open field. Under green house

condition, when comparing different percentages of shading (40 per cent, 60 per cent and 80 per cent), the highest yield was obtained with 40 per cent shading along with misting. In the case of floating covers, the highest yield was obtained from plants grown under PVA (Polyethylene vinyl acetate) and the lowest was recorded from those grown under Polyethylene with holes (Kwon, 1992).

A trial was conducted in Italy to evaluate the response of Chinese cabbage to thermal conditions. Two Chinese cabbage cultivars Granado and Tonkino were raised (26 December to 9 February) in three conditions (in open, cold green house and in heated green house) and transplanted in two systems (open field or cold green house). The yields from seedlings of both the cultivars raised in the open and in cold green house, cultivated on either system were zero. More than 80 per cent of seedlings of Tonkino plants raised in heated green house produced heads irrespective of the system of cultivation. The yield from Granado plants grown in a heated green house from seedlings raised in a heated green house were more than 40 t/ha (Noto and Leonardi, 1995).

SenYan *et al.* (1995) observed that shading Chinese cabbage using silver-grey polyvinylchloride net during hot season could increase yield by 35 per cent. YungWei (1995) reported that the survival rate and yield from cabbage transplants raised in greenhouse and plastic house were better than those raised in net house. The germination percentage, plant fresh weight and leaf area were found greatest in greenhouse followed by plastic house.

HyoDuk (1999) reported that the use of rain shelters combined with fertigation systems lead to good head formation in chinese cabbage along with successful prevention of soft rot (*Erwinia carotovora*) and virus diseases during high temperature periods in Korean lowlands. The cultivars meant for autumn season cultivation were successfully grown in summer season by using rain shelters.

In a study conducted in Tamil Nadu, cauliflower hybrid Pawas grown in naturally ventilated polyhouse formed curds earlier than those grown in the open field (Nagalakshmi *et al.,* 2001). Pulgar *et al.* (2001) investigated the effects of floating plastic row covers on the growth and quality of Chinese cabbage (*Brassica pekinensis* cv. Nagaoka 50) in Southern Spain for three years. The results showed that covering plants with polyethylene lead to greater plant production, yield and sugar concentration when compared to polypropylene row covers.

Suseela (2002) observed that 4.5m height naturally ventilated greenhouse, at 0% roof ventilation and 5% side ventilation is suitable for growing cauliflower in tropical conditions like Coimbatore. The average temperature rise (at 1m above the floor level) above the ambient temperature inside the structure was 3.45^0C.

A study was carried out with cabbage in a polyethylene film greenhouse, involving two cultivars (Golden Acre and Santorino) and two systems of protection: a simple one with plastic tunnel protection and a double one realized by the tunnel and a non-wooven crop cover that was placed immediately after planting. Plant height, leaf number and rosette diameter were affected by the system of protection at the beginning of vegetation. Golden Acre and Santorino recorded a yield of 43.9 and 50.5 t/ha respectively. The double system of protection provided a yield increase of 33.5 t/ha, which was 13.5 t/ha higher than the simple system of protection (Apahidean *et al.,* 2004).

Prabhakar and Hebbar (2006) reported that high quality and healthy seedlings could be obtained by raising seedlings with nylon net covering on nursery beds or hi-tech mass production using trays or flats in greenhouse (net or polyhouse).

An experiment was conducted with cauliflower cv. Dania in the hilly area of Darjeeling, West Bengal in three situations namely under high cost polyhouse, low cost polyhouse and open field condition; and in three growing seasons *viz*, summer, rainy and winter. The minimum days required for curd initiation (60.3 days) and the

highest per hectare yield of 54.79 t were observed under high cost polyhouse during winter. The maximum plant height was observed in cauliflower cultivated under high cost polyhouse in winter and the minimum was recorded in open field during summer season (Pradhan *et al.,* 2008).

Biotic and abiotic factors such as heavy rain, high temperature, weed competition and high incidence of pest and diseases are the main limitations for cauliflower production in open fields especially in hot areas. This often leads to yield losses and quality degradation both of which can be overcome by protected cultivation in combination with a suitable hydroponics system (Ranawana *et al*., 2008).

For cauliflower cultivation in Coimbatore, naturally ventilated gable roof greenhouse having 3.75m ridge height with 20% side ventilation and 6% roof ventilation oriented in North-South direction was found ideal while taking into consideration the suitability of the structure and economics. The frame of the green houses were constructed using locally available materials like casuarina poles and arecanut reapers while the cladding used was UV stabilized polyethylene sheets. Insect-nets were provided at the roof and side ventilators to prevent the entry of insects (Suseela, 2008b).

Cabbage and cauliflower gave an increased yield of 133 per cent and 89 per cent respectively when grown in rain shelters (Devadas and Gopalakrishnan, 2012). Anu *et al.* (2012) reported that some of the tropical varieties of cauliflower produced marketable curds during June-July (off-season) in Kerala when planted in rain shelter.

An experiment was conducted at Horticultural Research Station, Mondouri in West Bengal to determine the growth, yield and quality of four hybrids (*viz*, Early You, Princess, Fiesta and Nokguk) of sprouting broccoli under polyhouse and open field condition. The plants grown in polyhouse gave the highest yields in all four hybrids as compared to those in the open field. Results showed that polyhouse grown

plants were superior to open field grown plants in terms of quality attributes like chlorophyll a, chlorophyll b, total chlorophyll, reducing sugar, non-reducing sugar and total sugar (Thapa *et al.,* 2013).

In a study conducted in Philippines involving two types of protected structures (*viz*, house type structures built from either bamboo or coco lumber and tunnel type structures made of either bamboo or steel frames, with either plastic or net coverings), it was observed that the average yields were higher under protected cropping compared with the open field for cauliflower, green onion, lettuce, chilli pepper, tomato, sweet pepper, bitter melon, pechay (*Brassica rapa* cv. group pak choi), muskmelon, broccoli and string beans (Gonzaga *et al.,* 2013).

2.1.2. Influence of season/time of cultivation on growth and yield of cole crops

In two year trials, Tewari *et al.* (1977) observed that planting time has an influence on head shape in cabbage. Cabbage variety Golden Acre sown at 15 days interval from 27 May up to 15 July formed round heads while the percentage markedly declined in those sown from 30 July up to 15 August.

In an experiment with thirty six Chinese cabbage cultivars sown at monthly intervals from 27 March to 11 September in South Korea, Lee and Yoon (1978) noticed a decrease in average plant survival of cultivars with time for sowings from May to July as the temperature increased. There was significant correlation between the length and width of the largest leaf regardless of growing season and stage of growth.

Seasonal trials of tropical Chinese cabbage cultivars conducted in Bangladesh indicated that most varieties were well adapted to dry period while in the rainy season the range of adaptable varieties was narrow (Shinohara, 1981). Cauliflower cultivar White Contessa was evaluated in the summer and winter season at La Lima, Honduras in order to assess its adaptability to tropical lowlands. The marketable yield

in the winter was 9.66 t/ha while in the summer it was 0.33 t/ha (Ton and Alfonso, 1982).

Kobryn (1987) reported that among the three dates of sowing (*viz*, 15 August, 30 August and 15 September), 15 August sowing of Chinese cabbage in green house resulted in highest yield (7.2 kg/m^2). In two year trials, seeds of cultivar Golden Acre were sown round the years at 15 days interval in which the average yields ranged from 3.64 t/ha for the crop sown on 15 May to 37.84 t/ha for that sown on 1 November (Lawande *et al.,* 1988).

Castillo *et al.* (1991) observed that in Snowball type cauliflower cultivars, the vegetative period was lengthened and curd formation period was shortened with later sowing (January to March). Eryilmaz and Varis (1994) reported that in a green house experiment with five Chinese cabbage cultivars (Tokat-2, Tokat-5, Tokat-29, Tokat-89 and Green Rocket F_1) sown on three different dates *viz*, 10 August, 13 September and 7 October, Tokat-89 sown on 13 September gave the best plant weight and head quality.

Saikia *et al.* (1998) studied on the effect of transplanting date (14 August, 29 August, 13 September and 28 September) on the growth and yield of seven cultivars of early cauliflower grown under a UV stabilized LDPE (Low density polyethylene) rain shelter. Best yields were obtained from all cultivars when seedlings were transplanted on 29 August. Among the cultivars, Pusa Katki recorded the highest curd yield when transplanted on 29 August (153.82 kg/100 m^2).

The influence of different growing seasons on the yield and quality of Chinese cabbage (*Brassica pekinensis*) was investigated at Lithuanian Institute of Horticulture. The spring frosts, cool weather in May and high temperatures in the summer months resulted in flowering prior to head formation and there was no production of inflorescence in the autumn season. Lower levels of nitrates, dry matter

and vitamin C were observed in summer due to the prevalence of hot weather (Staugaitis and Starkute, 1999).

In an experiment to find out the possibility of off-season production of cabbage hybrids (Bajrang, Green challenger, Bharati and Varun) during summer period under mid-hill conditions of Himachal Pradesh, the hybrid Varun recorded higher value for head size (195.9 cm^2) and head weight (1.147 kg). Among the four different dates of transplanting tested, (*viz*, 7th April, 17th April, 27th April and 7th May), 7th April transplanting resulted in higher yield (Sharma and Sharma, 2001).

Islam *et al*. (2002) reported that among three planting dates (15 November, 30 November and 15 December) tried on cabbage cultivar Atlas-70, 30 November planting resulted in the highest marketable yield (82.10 t/ha).

According to Pradeepkumar *et* al. (2002), out of the six cultivars of cauliflower (PES-1, F1-598, PES-3, Pusa Early Synthetic, Pusa Sharad and Super Snowball) planted in the open field, PES-1 was superior in all the planting dates and the highest yield (7.51 t/ha) was recorded in early planting. Significant interaction was found between varieties and planting time with respect to number of days to maturity, stalk length, number of leaves and yield.

A study was conducted during rainy season at Vegetable Research Centre, Pantnagar in order to find the effect of three planting dates (26 July, 10 August and 25 August) and growing environment (open field flat planting, open field ridge planting, planting in low plastic tunnel and planting in low-cost poly house) on vegetative and yield characters of cauliflower cultivar Pant Gobhi-4. The highest yield (19.46 t/ha) was observed in the crop planted on 10 August in low-cost poly house. With regard to vegetative characters like plant spread, number of leaves per plant, leaf length and leaf width, 26 July planted crop was found superior (Srivastava *et al.*, 2002).

Esmail (2004) reported that sowing of Chinese cabbage on 10, 25 September and 10, 25 October under the conditions of EL-Bahaira Governorate, Egypt increased the length, width and weight of heads along with minimum values of total defects.

A study was conducted at experimental farm of Highland Agricultural Research and Extension Centre of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Kukumseri during two summer seasons in order to find out the best time for transplanting cauliflower (*Brassica oleracea* L. var *botrytis* L. subvar *cauliflora* DC). The interaction effect between different planting dates (18 May, 2 June and 17 June) and cultivars (Pusa Snowball K1, Palam Uphar and Pusa Himjyoti) indicated that transplanting of Pusa Snowball K1 on June 2 gave maximum marketable curd yield (24.7 t/ha) along with better performance in average curd weight, gross curd weight, net curd weight, curd diameter and curd size index. This combination resulted in maximum net returns (Rs. 257000/ha) and a benefit cost ratio of 6.4:1 were also obtained from the same (Sharma *et al*., 2006).

Diaz *et al.* (2007) carried out an experiment at INIVIT (Research Institute of Tropical Root and Tuber Crops, Bananas and Plantains), Cuba to analyze the performance of Chinese cabbage hybrids viz, Tokyo Bekana and Maruja Santoh in different planting times. The hybrid Tokyo Bekana produced the best yield (23.58 t/ha) in the summer season (April-July) whereas in the winter season (December-March), the variety Nagaoka which was used as control out yielded both the hybrids.

Field experiments were conducted involving thirty two hybrids and open pollinated varieties of cabbage during long rainy season (March to May/June) and short rainy season (September to December) at AVRDC - The World Vegetable Center, Regional Center for Africa, Tanzania. Results revealed that for each season, among varieties there was significant difference in marketable head yield. During the long rainy season, Gloria F_1 and Victoria F_1 were found best for head yield while

Quick Start and Rotan performed best during the short rainy season (Adeniji *et al*., 2010).

The effects of different transplanting time on growth, yield and quality of various cabbage varieties and hybrids were investigated in an experiment carried out at the Research Farm, ICAR Research complex for NEH Region, Mizoram. Date of transplanting significantly affected the number of non-wrapper leaves, weight of non-wrapper leaves, gross plant weight, polar length, equatorial length, net head weight, harvest index, head compactness and yield. It was observed that maximum yield potential of various cultivars was apprehended by transplanting of cabbage seedlings on 1st December (Singh *et al*., 2010).

Zagade *et al.* (2010) observed that cabbage cultivar Golden acre sown on 15th October produced significantly higher yield than delayed sowing on 30th October and 15th November.

Performance analysis of four tropical cabbage hybrids (NS 183, NS 43, NS 35 and Disha) under open and protected conditions during off-season (rainy season) and on-season was conducted at College of Horticulture, Vellanikkara, Thrissur and the results indicated that all the hybrids grown under rain shelter during off-season gave lower yield when compared to on-season crop raised in rain shelter. It was also observed that during off-season, in the open field, none of the four hybrids formed heads while in the rain shelter, head formation was noticed in all the hybrids and the highest net head weight (553.50 g) was recorded for NS 43 (Malu, 2011).

A field experiment was carried at College of Horticulture, Vellanikkara involving two tropical hybrids (Basant and Pusa Karthik Sankar) with five planting times at an interval of 15 days (1st November, 15th November, 1st December, 15th December and 1st January). When considering higher economic yield, among five different dates for transplanting cauliflower, both the cultivars performed best when transplanted on 1st November. It was also observed that the weather experienced

during the transplanting to curd initiation period had more influence on curd weight than the weather prevalent during curd initiation to curd maturity (Karthika *et al*., 2013).

According to Nooprom and Santipracha (2013), selection of suitable planting dates and varieties are crucial for successful cultivation of broccoli in rainy season in Thailand. An experiment conducted at Sher-e-Bangla Agricultural University, Dhaka revealed that planting time has significant effect on plant characters like plant height, number of leaves, number of non-wrapper leaves, fresh weight of head, diameter of head, dry matter of head, and moisture content in cabbage (Ullah *et al.,* 2013).

A field trial was conducted in China to investigate the effects of different sowing dates (20 February, 28 February, 15 March, 25 March and 5 April) on the yield of Chinese cabbage variety Jinqian 65. It was observed that 15 March sowing is the best sowing date to obtain high vegetable yield and high marketable percentage (YueYong, 2013).

2.2. CULTIVARS

Eight exotic cabbage hybrids and two standard varieties (Pride of India and Golden acre) were evaluated at Hyderabad during the rabi season for yield, borer (*Hellula undalis*) resistance and ten yield components. Four hybrids (IDCBH38, IDCBH37, TKCBN28 and TKCBN25) significantly out yielded the two standard varieties and gave yields ranging from 31-51 t/ha while the standard varieties could yield only 23-28 t/ha. Among the four high yielding hybrids, TKCBN25 produced the most compact heads, had the shortest growth period (45 days), lowest borer attack and highest productivity. The hybrid IDCBH38 showed similar results as TKCBN25 except that it had long growth period of 80 days and moderate resistance to borer attack (Srihari and Satyanarayana, 1992).

Bharadwaj *et al.* (1993) assessed eight cabbage (*Brassica oleracea* var. *capitata*) hybrids and three control cultivars (Golden Acre, Pride of India and Sel 8) for six quantitative traits. The number of days to reach maturity ranged from 84 days for Golden Acre to 102 days for TKCBH30. The highest head weight was observed for TKCBH28 (1034 g) followed by Sri Ganesh (988 g) and TKCBH27 (957 g). The three hybrids namely TKCBH27, TKCBH28 and Sri Ganesh gave the highest marketable yields of 38.8 t/ha, 36.7 t/ha and 34.9 t/ha respectively.

In a trial with seven cultivars of early cauliflower evaluated under a UV stabilized LDPE (Low density polyethylene) rain shelter in India, Saikia *et al.* (1998) reported that the cultivar Heavy Silver Plate exhibited significantly better growth and curd yield (114.01 kg/100 m^2) across the four transplanting dates *viz*, 14 August, 29 August, 13 September and 28 September.

Agronomic behaviour of fifteen commercial cabbage genotypes were evaluated in Brazil and the best yields were obtained from the hybrids Shinsei (54.8 t/ha) followed by Japones (53.6 t/ha), Astrus (48.6 t/ha) and Kenzan (44.8 t/ha). While considering the market preference for cabbages of 1-1.5 kg, the best genotypes were Saiko, Uyutoya, Chato de Quintal and Midori which gave yield in the range of 32-40 t/ha (Fracaro *et al*., 1999).

Greenland *et al.* (2000) conducted cabbage hybrids trials at the Oakes Irrigation Research Site in North Dakota, USA in order to evaluate hybrids for yield and quality characteristics. For fresh market purpose, three hybrids namely Gideon, Bronco and Royal Vantage produced the highest yields along with best appearance. The hybrids with highest yields and best appearance for processing market were found to be Fresco, Cheers, Bravo and Bronco. It was also observed that despite the differences in weather during the long study period, the cabbage hybrids showed consistency in yield and quality.

The experiments carried out at New Delhi in order to study the genotype and environmental reaction of varieties and hybrids of early cauliflower during the late kharif seasons revealed that among varieties, significant differences were observed for characters namely yield per plot, maturity days, harvest index and riceyness. It was observed that the varieties DC 41-5 and DC 98-4 along with hybrids viz, CH 341, CH 541 and CH 598 were best suited in less favourable environments (Sharma *et al*., 2000).

Sharma and Verma (2000) reported that in a field experiment carried out in Himachal Pradesh during the summer season involving five cultivars of cabbage (viz, Bahar F_1, KGAT, Pusa Mukta, Pride of India and Golden Acre), the hybrid Bahar and Pusa Mukta recorded a yield of 30.79 t/ha and 22.27 t/ha compared with the commercially grown cultivar Golden Acre (14.39 t/ha).

In a study conducted at Kerala Agricultural University, significant difference was observed for all characters under study for all the seven lines of cabbage tested *viz*, Questo, DTC 513, Pusa Ageti, DT-507-4, Golden Acre, Japanese Hybrid and Red Cabbage. Pusa Ageti, DTC 513, DTC-507-4 and Red Cabbage were the earliest to form head and were statistically on par. The highest number of non wrapping leaves was produced by Questo (KAU, 2001).

An experiment was conducted during rabi season involving nine exotic cabbage hybrids for finding the best high yielding variety appropriate to the agro climatic conditions of Pakistan. The hybrid Field Mark produced the heaviest heads weighing on an average 3.56 kg each. Field Mark had the maximum plant girth (72.45 cm), took 154.75 days to reach maturity and gave the highest yield of 98.76 t/ha (Khokar *et al.,* 2001).

Pandey *et al*. (2002) reported that in a field study involving sixteen commercial cabbage hybrids assessed for suitability and production potential in Pithoragarh, Uttar Pradesh, the hybrid PT-23 gave the highest biological yield

followed by PT-22 and Green Cornet. The maximum number of outer leaves was recorded in Krishna and the minimum was in PT-5. Early maturity was observed in hybrids Sprint Ball, PT-7 and PT-5 while other hybrids exhibited medium and late maturity.

In a field experiment conducted in the Dominican Republic to compare the yield, earliness, head characteristics and damage caused by diamond back moth larvae in eleven cabbage hybrids, the highest yield was obtained from the hybrid Genesis. Among the hybrids, Bravo and Express showed greater damage by diamond moth larvae. It was observed that in terms of yield, earliness, head shape and losses due to diamond back moth larvae, Green Cup, Blue Vantage and Genesis were comparable or superior to the standard hybrid Izalco (Morales-Payan and Stall, 2004).

Five Chinese cabbage hybrids namely Manoko, Mirako, Nikko, Optiko and Bilko were tested in Lithuania in order to identify the most productive hybrids possessing the best internal quality and having tolerance to average night and day temperature lower than 10^0C along with tolerance to short-term frosts of 3-5^{0}C. The hybrid Mirako recorded the maximum head weight of 914 g whereas the minimum was recorded in the hybrid Bilko (814 g). The highest amount of inverted sugar was found in the heads of Bilko and Mirako (1.76 per cent) and the lowest in Manoko (1.43 per cent). With regard to marketable yield, the highest value was observed for Manoko (37.6 t/ha) followed by Nikko (34.5 t/ha) and Optiko (34.0 t/ha). Staugaitis *et al.* (2004) remarked that the average weight of head, soluble solids, total solids and nitrates were depended mainly on climatic conditions and not on hybrids.

In addition to the prevailing agro-ecological conditions and agronomic practices used, the correct choice of a hybrid is of great importance as it allows the genes that control head mass to be fully expressed thus minimizing the effects of limiting environmental factors (Cervenski *et al.*, 2007).

A field experiment was taken up in Uttarakhand in the Kharif season, in order to evaluate the performance of eight cabbage hybrids namely S-990, S-92, Riya, S-96, S-991, Pragati, Varun and Kishan. The mean yield of hybrids ranged from 22.6 t/ha to 30.6 t/ha. The hybrid S-92 gave the maximum yield of 30.6 t/ha followed by S-96 with 30.0 t/ha. Variation was observed among hybrids for duration of maturity. S-96 and Pragati were the earliest (65 days) to mature. S-92, S-991 and Kishan took 75 days to reach maturity while Riya and Varun took 80 and 85 days respectively to achieve maturity. Most of the hybrids exhibited round head shape, except S-92 and Varun which formed semi-round shaped heads (Bhatt *et al.,* 2008).

A study carried out to evaluate the performance of various cabbage hybrids in mid-hill conditions of Uttaranchal revealed that DARL-801 producing compact, round heads with a mean head weight of 2.35 kg, reaching early maturity (65.5 days) with high nutritional value, was the most suitable hybrid for the region (Pandey *et al.,* 2008).

A relative evaluation of yield characteristics of different cabbage varieties were undertaken in different types of green houses and open field in Kerala. The cultivars NS 43, NS 183 and Gaurav performed well and the maximum yield was obtained in greenhouses having a height of 4.15m oriented in North-South direction (Suseela, 2008a).

Experiments carried at Agricultural Research Station, Mannuthy revealed that cabbage lines NS 43 and NS 160 performed well giving high yields under Kerala conditions (KAU, 2009). Pradeepkumar and George (2009) reported that during the period from October to March, F_1 hybrids of cabbage, Quisto and Hari Rani Gol performed well in the plains of Kerala.

In a study conducted at Mizoram involving various varieties and hybrids of cabbage, it was observed that the cultivars KGMR-1 and Golden Acre showed better head yield potential. The cultivar INDAM-1299 produced the most compact head

followed by Golden Acre, NS 160, KGMR-1 and Ryozeki. It was concluded that the cultivars KGMR-1 and Ryozeki are suitable for leaf production during summer and rainy seasons as they produced higher plant biomass (Singh *et al*., 2010).

In an experiment conducted in Romania, under polyethylene tunnels involving two early hybrids (Comparsa F_1 and Famosa F_1) of savoy cabbage, Famosa F_1 performed better than Comparsa F_1 in plant growth, yield and resistance in cabbage cracking. It was observed that cultivation of suitable early hybrids under protected condition is necessary to obtain early and high yields in Transylvania region (Apahidean *et al.,* 2010).

A study was under taken in Kerala Agricultural University to evaluate the yield and post harvest quality attributes of different genotypes of cabbage and cauliflower in the plains and higher altitudes of Kerala. The results revealed that in terms of high head yield, head weight, head height, head solidity, early maturity and better adaptability, cabbage hybrid NS 183 was the best performing genotype in high altitude region whereas in the plains Tropical Sun Plus performed the best. There was significant difference in yield of cabbage which ranged from 22.6-29.3 kg/m^2 in hills and 1.27-22.06 kg/m^2 in plains. In the case of cauliflower, considering curd yield, curd weight, curd height and curd solidarity, the genotype NS 133 was found suitable to high altitude region while in the plains, NS 60 proved to be the best. Significant difference was noticed between cauliflower genotypes with regard to curd weight in the plains (Elavarasan, 2011).

A study conducted at Kerala Agricultural University revealed that among four cabbage hybrids (*viz*, NS 35, NS 183, NS 43 and Disha), NS 43 was found ideal for protected cultivation during off- season while NS 35 was found suitable for on-season cultivation under both (open and protected) systems (Malu, 2011).

Rajanna and Shivashankar (2012) reported that in an experiment to evaluate the performance of cabbage F_1 hybrids during rabi season under hill zone of

Karnataka, the highest yield was recorded by Krishna (71.08 t/ha) followed by Shristi (69.68 t/ha) and Rajrani (68.92 t/ha). The highest head diameter was observed for Krishna (18.29 cm) followed by Shristi (18.27 cm) and Rajrani (18.07 cm). Lower incidence of diamond back moth was also recorded in these three hybrids.

2.3. PEST AND DISEASE INCIDENCE

Scaife and Clarkson (1978) reported that the incidence of crop disorders like leaf tip burn in cabbage and internal browning in Brussels sprouts are known to be due to calcium deficiency. Moreover it has little relation to soil calcium status but is more related with particular type of weather. He also reported that wet weather and other unfavourable soil physical conditions like compaction leads to a temporary reduction in the proportions of the distal undifferentiated region of roots where most calcium uptake occurs.

According to Horiuchi and Hori (1980), club root disease in crucifers can occur at more than 46 per cent of maximum water holding capacity and the severity increases with increase in soil moisture. Furthermore, the most severe attack occurs under water logged conditions.

The major problems that are often encountered when Chinese cabbage is grown at high temperatures are loose head formation, tip burn and soft rot (Kuo and Tsay, 1981). Chari and Patel (1983) reported that among the different pests infesting cabbage, tobacco caterpillar, *Spodoptera litura* F. is the most important polyphagous pests distributed throughout the south eastern region in the world.

The cultivation of cauliflower is hampered by the incidence of several pests such as the diamondback moth (*Plutella xylostella* L.), the tobacco caterpillar (*Spodoptera litura* F.), and the mustard aphid (*Lipaphis erysimi* K.) resulting in significant yield loss (Dhamo and Jotwani, 1984).

Alternaria blight caused by *Alternaria brassica* is the most serious and widespread disease of cole crops all over the world. The yield losses up to an extent of 10 to 70 per cent due to this disease have been reported in different *Brassica spp.* from different countries (Kolte, 1985). Munden and Bailey (1989) observed that slug damage to Chinese and spring cabbage was increased after rain but was negligible after heavy frost.

Experiments were conducted at the AVRDC green house in Japan to investigate the relationship between the incidence of tip burn and the time of application, source and concentration of nitrogen. It was observed that the application of nitrogen in ammoniacal form increased the incidence of tip burn. From green house studies conducted during 1984-1985 in order to develop integral cultural practices to alleviate the occurrence of tip burn in Chinese cabbage it was concluded that covering the outer leaves with red film, black vinyl sheet or rice straw from the time of transplanting to head formation; irrigation through pipes buried at 10 or 20 cm depth; application of citric acid foliar spray and split application of liquid nitrogen reduced the incidence of tip burn (Imai, 1990).

Saure (1998) reported that serious economic losses can be caused due to tip burn, a physiological disorder which is seen as necrosis at the margins of young developing leaves in the inner part of vegetable plants, mainly of head forming vegetables such as lettuce (*Lactuca sativa* L.), white cabbage (*Brassica oleracea* L. var. *capitata*), Chinese cabbage (*B. pekinensis*), and Brussels sprouts (*B. oleracea* var. *gemmifera*).

Among different bioagents used against tobacco caterpillar (*Spodoptera litura*), NPV (Nuclear Polyhedrosis Virus) has been most widely studied for its virulence, pathogenicity, mass production, safety and field efficacy in controlling them on cabbage, groundnut, sunflower and tobacco (Jayaraj *et al*., 1999).

According to Sharma *et al.* (2006), in cauliflower, *Sclerotiana* stalk rot index was maximum (30 per cent) during February-March at a temperature of 18-22^{0}C, whereas *Alternaria* leaf spot index was highest (>30 per cent) in November-February at temperature range between 20 and 28^{0}C.

Patait *et al.* (2008) reported that the population of *Crocidolomia binotalis*, *Hellula undalis, Plutella xylostella*, and *Spodoptera litura* on cabbage varied from 3.8 to 44, 1.0 to 6.2, 0.6 to 1.6 and 0.6 to 3.2 larvae per quadrat during rainy season and 1.0 to 5.0, 1.0 to 1.6, 1.6 to 20.4 and 0.2 to 1.0 during winter season. During rainy season, the population of *C. binotalis, P. xylostella* to the maximum extent was influenced positively by forenoon relative humidity and rainfall. The population of *S. litura* was influenced positively by forenoon relative humidity and negatively by minimum temperature and afternoon relative humidity.

Rapid plant growth, high temperature and high levels of nitrogen make cabbage plants more vulnerable to the development of tip burn. Plants experiencing such conditions are incapable of supplying sufficient calcium to actively growing inner young leaves at a critical point. Since the calcium is fixed by the outer leaves and not further translocated to the young growing leaves, neither soil nor foliar application of calcium will be effective in alleviating tip burn (Rana, 2008).

Adeniji *et al.* (2010) reported that loose heads, a disagreeable horticultural characteristic in cabbage, is found associated with a high incidence of cabbage head caterpillar and occurs if attacked by the same at an early growth stage.

Soft rot (*Erwinia carotovora* sub sp. carotovora) is one of the destructive diseases of vegetables including cabbage worldwide (Bhat *et al.,* 2010). Bunescu *et al.* (2010) reported that use of attractant traps with alimentary baits such as beer had good efficacy in controlling slugs in green houses.

A study was conducted to estimate control thresholds for managing tobacco caterpillar (*Spodoptera litura*) at different larval densities and growth stages of Chinese cabbage in field conditions. The number of larvae (2^{nd} to 3^{rd} instar) which caused 5 per cent loss of yield was estimated as 2.9 per 100 plants five days after transplanting and 5.6 per 100 plants 20 days after transplanting (DuckSoo *et al*., 2011).

In a study conducted in college of Horticulture, Vellanikkara, Malu (2011) reported the incidence of head rot in cabbage caused by *Alternaria brassicae* in open field conditions during off- season. Damping off caused by *Pythium spp.* was also noticed in cabbage during nursery stage. Tobacco caterpillar (*Spodoptera litura*) was the major pest in cabbage cultivated during off- season inside rain shelter. Among the four hybrids cultivated in rain shelter during off-season, the lowest pest incidence was noticed in NS 35 (2.5%) followed by Disha (7.5%), NS 183 (15%) and NS 43 (20%). During off-season inside rain shelter, minimum disease incidence was observed in NS 183 (2.5%) followed by Disha (15%), NS 43 (17.5%) and NS 35 (25%). No major disease incidence was noticed both under rain shelter and in open field during on- season.

Narasimhamurthy *et al.* (2012) observed that among different plant extracts used in combination with SLNPV (*Spodoptera litura* Nuclear Polyhedrosis Virus) (250 LE per ha) under field condition against tobacco caterpillar (*Spodoptera litura*) on cabbage, the highest per cent (81.66%) larval reduction was recorded in combination with neem seed kernel extract at 5%.

Population dynamics of major insect pests and their natural enemies on cabbage were studied during rabi season and it was observed that the peak population of diamond back moth was recorded on 1^{st} March and 23^{rd} February. The population build up of diamond back moth was influenced by both maximum and minimum temperature while cabbage aphid population was enhanced only by maximum

temperature. It was also observed that relative humidity and rainfall had negative influence on pests and natural enemies (Patra *et al.*, 2013).

In surveys conducted in Himachal Pradesh, infestation of *Plutella xylostella* (diamond back moth) was noticed in poly house grown cole crops (cabbage and chinese cabbage) and it recorded a population ranging from 0.40 - 0.90 larvae/plant (Vashisth *et al*., 2013).

Among pests observed in studies conducted at three localities in Tamil Nadu with varied ambient temperature ranges, Lepidoptera occupied 46 per cent followed by Hemiptera 27 per cent, Coleoptera 9 per cent, Orthoptera 9 per cent and Acari 9 per cent (Raja *et al.,* 2014).

In a survey conducted during rabi season of 2007 and 2008 in Varanasi, Uttar Pradesh of cabbage, *Brassica oleracea* L. var. *capitata* fields, 23 different insect pests species with seven different orders were recorded. The maximum (31 per cent) insect pest species belonged to the order Lepidoptera and the minimum (5 per cent) belonged to the orders Diptera and Isoptera. Diamond back moth (*Plutella xylostella* (L.)) and cabbage head borer (*Hellula undalis* Fab) were higher in population (Yadav *et al.,* 2014).

2.4. ECONOMICS OF CULTIVATION

According to Tripathi (1999), the operational cost and commercial cost were Rs. 2215/ha and Rs. 794/ha respectively for the cultivation of cabbage in high-hills of Uttar Pradesh. Labour cost accounted for nearly 74 per cent of the total cost whereas material cost was about 16 per cent.

Pandey *et al.* (2001) reported that the cost of cultivation of off-season cabbage in Shimla was Rs. 34880/ha with a benefit-cost ratio of 1.4 and the maximum contribution to cost was by human labour (43.3 per cent). The average cost of

cultivation per ha for cauliflower production in Durg, Chhattisgarh was estimated as Rs. 25228.57 whereas the average gross return per ha was Rs. 48516.20 (Singh and Banafar, 2006).

Studies on the year round cauliflower production in open and under cover conditions in the hills of Darjeeling district revealed that cultivation inside high cost poly house is not feasible in the region due to high erection cost and very low wholesale price. Compared to protected conditions the benefit-cost ratio was higher in open conditions during winter and summer (Pradhan *et al*., 2008).

Suseela (2008 b) obtained benefit-cost ratio for cauliflower cultivation in 3m, 3.75m and 4.7m height green house as 1.528, 2.286 and 2.293 respectively. Frequent weeding and more attack of pest and diseases lead to lower benefit-cost ratio (1.168) for open field cultivation. According to Bala *et al.* (2011), the cost on plant protection chemicals constituted 42 per cent of the total cost of production of off-season cabbage in Kullu district of Himachal Pradesh, followed by cost of seed/seedlings (24 per cent) and farm yard manure cum fertilizers (21 per cent).

The total cost of cabbage cultivation in Thrissur, Kerala during off-season and on-season inside rain shelter, were recorded as Rs. 48.30 per m^2 and Rs. 47.90 per m^2 respectively. The benefit-cost ratio of rain shelter crop during the off- season was 1.14. The total cost of cultivation under open field condition during on-season was less (Rs. 23.00 per m^2) and the benefit-cost ratio obtained was 2.66 (Malu, 2011).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled 'Standardization of planting time for off-season cabbage (*Brassica oleracea* L. var *capitata)* production in rain shelter' was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during May - October 2013 (off-season) with the objective to standardize planting time for off-season cabbage (*Brassica oleracea* L. var *capitata*) production in rain shelter.

The site is located at 10^0 31'N latitude and 76^0 13'E longitude and at an altitude of 22.25m above mean sea level. The area enjoys a typical warm humid tropical climate and receives an average rainfall of 3400 mm per year. The soil of the experimental site comes under the textural class of sandy clay loam and is acidic in reaction. The materials used and methods followed are presented below.

3.1. PROTECTED STRUCTURE

Two low cost rain shelters in the Department of Olericulture were used for the study and the design used was RBD. The frame of the rain shelters was made up of G.I pipes. Cladding was provided with UV stabilized low density polyethylene film (UVLDPE) having a thickness of 200 micron. The floor area of each of them were $100m^2$ (20 m x 5 m) with a side height of 2m and central height of 3.5m.

3.2. VARIETY

NS 43, F_1 hybrid from Namdhari seeds Pvt. Ltd, found ideal for protected cultivation during off-season (Malu, 2011) was used for the present study (Plate 1.). It is a uniform vigorous early maturing hybrid (85-90 days), with green to light green foliage and having tolerance to black rot. The head is flat, medium and firm. NS 43 is a typical tropical cabbage suited for fresh market.

Plate 1. Cabbage hybrid NS 43

3.3. DESIGN AND LAYOUT OF THE EXPERIMENT

The experiment was laid out in Randomized Block Design (RBD) with four replications. The general view of the experiment plot is given in plate 2. The details of the technical programme are given below.

Plot size: 5.4 m^2

Spacing: 60 cm x 45 cm

No. of treatments: 6

Treatments:

The treatments include the following dates of planting:

T_1: May 15th

T_2: May 30th

T_3: June 15th

T_4: June 30th

T_5: July 15th

T_6: July 30th

No. of plants per replication: 20

3.4. CULTURAL OPERATIONS

3.4.1. Nursery practices

The seeds of NS 43 were sown successively at an interval of 15 days from April 15th to June 30th in plug trays filled with rooting medium consisting of vermicompost and sand in the ratio of 1:1. The plug trays were irrigated twice a day

Plate 2. The general view of the experiment plots

using rose can. The seedlings were drenched with *Pseudomonas fluorescens* (20g/L) to prevent nursery diseases. Two weeks after sowing, a urea solution (10g/L) was sprayed to the seedlings to improve their growth. The trays were kept under polyhouse.

3.4.2. Land preparation and planting

The experimental field (rain shelter) was cleared and divided into plots of area 5.4m^2 (3 m x 1.8 m). Ridges and furrows were taken in each plot. The basal dose of farm yard manure at the rate of 25t/ha was applied and incorporated into the furrows. One month old healthy seedlings (Plate 3.) were transplanted to the furrows in the main field. The plants were irrigated as and when required. Gap filling was done up to one week after transplanting.

3.4.3. Fertilizer application

Urea, Factamphos and Muriate of Potash were the source materials for supplying nutrients viz, N, P_2O_5 and K_2O respectively. These nutrients were mixed based on the package of practices recommendation 150:100:125 kg/ha (KAU, 2011). Full dose of P_2O_5 and half dose of N and K_2O were applied one week after transplanting and the remaining half dose of N and K_2O were applied one month after transplanting.

3.4.4. After cultivation

Earthing up was done one month after transplanting and weeding was done regularly. Diseased and damaged plants were removed.

3.4.5. Plant protection

NPV (Nuclear Polyhedrosis Virus) 1ml/2L, Fame 1ml/10L and Ekalux 2ml/L were sprayed in the main field to control *Spodoptera litura* F.

Plate 3. One month old seedlings for transplantating

3.4.6. Harvesting

Heads were harvested at marketable stage and observations were recorded.

3.5. QUALITATIVE AND QUANTITATIVE OBSERVATIONS

Five plants per replication of each treatment were selected for recording the observations. The qualitative and quantitative observations were recorded as per the descriptor of NBPGR (Srivastava *et al.,* 2001). The following are the qualitative and quantitative observations which were recorded during the current study.

3.5.1. Plant spread (cm)

Plant spread was recorded as the average distance between two outer leaves of selected plant and expressed in centimeter.

3.5.2. Number of non wrapping leaves

Non wrapping leaves or the leaves that do not cover the head portion of the selected plants were counted at marketable stage and the mean value was taken.

3.5.3. Number of wrapping leaves

Wrapping leaves that cover the head portion of the selected plants were counted at marketable stage and the mean value was recorded.

3.5.4. Days to 50% head formation

It was recorded as the number of days from transplanting to the date when at least 50% of the plants attained head formation.

3.5.5. Days to 50% head maturity

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

3.5.6. Total number of marketable heads

Total number of heads which were of marketable quality in each plot was recorded.

3.5.7. Head compactness

Compactness of heads at marketable stage was recorded as per the following scores

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

3.5.8. Head shape

Shape of the heads were recorded at marketable stage as

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

3.5.9. Head length (cm)

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

3.5.10. Head breadth (cm)

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

3.5.11. Head index

Head index was calculated as the average of the ratio of head length to head breadth of selected heads at marketable stage.

3.5.12. Core length (cm)

The average of the length of the core region of selected heads at marketable stage was recorded and expressed in centimeter.

3.5.13. Stalk length (cm)

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

3.5.14. Gross head weight (g)

It was recorded as the average of the weight of selected heads along with their non wrapping leaves and stalk at marketable stage.

3.5.15. Net head weight (g)

Net head weight was recorded as the average of the weight of selected heads.

3.5.16. Harvest index

Harvest index was calculated as the ratio of net head weight (economic yield) to gross head weight (biological yield) of selected heads.

3.5.17. Pest and disease incidence

Percentage of plants affected by pests and diseases were recorded.

3.5.18. Yield/plot (kg)

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

3.5.19. Moisture content (%)

The moisture content of cabbage head was determined using a hot air oven. A weighed sample of cabbage head was subjected to drying in a hot air oven at 105^0 C till consistent weight was achieved and the difference in fresh weight and dry weight gave the weight of moisture which was expressed as percentage.

3.6. ECONOMICS OF CABBAGE PRODUCTION IN RAIN SHELTER

The economics of cabbage production inside rain shelter during off-season was worked out. Total return was estimated with realized yield. The benefit:cost ratio of cabbage cultivation in rain shelter during all the planting dates were worked out.

3.7. STATISTICAL ANALYSIS

The recorded data on vegetative and yield characters were statistically analyzed by using the statistical package MSTAT-C (Freed, 1986).

RESULTS

4. RESULTS

The observations recorded on various growth and yield characters during the study period were statistically analyzed and the results are presented below.

4.1. Quantitative characters

4.2. Qualitative characters

4.3. Pest and disease incidence

4.4. Benefit-cost ratio

4.1. QUANTITATIVE CHARACTERS

4.1.1. Plant spread

There was no significant difference in plant spread with respect to dates of planting. However the maximum plant spread (59.90 cm) was recorded in May 30th planting and the minimum (56.93 cm) was recorded in June 30th planting. The mean plant spread was 58.45 cm (Table 4.1).

4.1.2. Number of non wrapping leaves

There was no significant difference between planting dates with respect to the number of non wrapping leaves. The maximum number of non wrapping leaves (8.35) was found for June 15th planting and the minimum number (7.15) was observed for May 30th planting (Table 4.1).

4.1.3. Number of wrapping leaves

The treatments showed significant difference with respect to number of wrapping leaves. The maximum number of wrapping leaves (6.15) was observed for June 30th planting which was on par with July 15th (5.95) planting. The minimum number of wrapping leaves was recorded in May 30th planting (3.9) which was on par

with May 15th (4.0) followed by June 15th (5.15) and July 30th (5.40) planting. The mean number of wrapping leaves for all treatments was 5.09 (Table 4.1).

4.1.4. Stalk length

Planting dates had no significant effect on stalk length. However the highest value for stalk length was observed for May 30th (3.45 cm) planting followed by May 15th (3.13 cm), July 30th (2.93 cm), July 15th (2.85 cm), June 15th (2.73 cm) and June 30th (2.64 cm) planting. Mean stalk length for all the treatments was observed to be 2.96 cm (Table 4.1).

4.1.5. Days to 50% head formation

There was significant difference among planting dates with regard to days to 50% head formation. The minimum number of days to achieve 50% head formation was noticed for May 30th (47.9 days) planting which was on par with May 15th (48 days) planting. The maximum of 59 days to achieve 50% head formation was observed for June 30th planting and July 15th planting which were on par with all other treatments. The mean number of days to achieve 50% head formation was 53.94 (Table 4.2). Cabbage plants at head formation are shown in Plate 4.

4.1.6. Days to 50% head maturity

The treatments showed significant difference with respect to 50% head maturity. The minimum number of days to achieve 50% head maturity was observed for May 30th (63.75 days) planting which was on par with July 30th (67 days) and May 15th (68 days) planting. The maximum days to obtain 50% head maturity was observed for June 30th (75.50 days) planting followed by July 15th (73.25 days) and June 15th (70.75 days) planting. The treatments took on an average 69.71 days to reach 50% head maturity (Table 4.2). Cabbage plants at head maturity are shown in Plate 5.

Plate 4. Cabbage plants at head formation stage

Plate 5. Cabbage plants at head maturity stage

Table 4.1. Plant spread, number of wrapping leaves, number of non wrapping leaves and stalk length in different planting dates

Planting dates	**Plant spread (cm)**	**Number of non wrapping leaves**	**Number of wrapping leaves**	**Stalk length (cm)**
May 15th	57.71	7.35	4.00	3.13
May 30th	59.90	7.15	3.90	3.45
June 15th	57.69	8.35	5.15	2.73
June 30th	56.93	7.80	6.15	2.64
July 15th	58.68	8.00	5.95	2.85
July 30th	59.78	8.30	5.40	2.93
Mean	58.45	7.83	5.09	2.96
CD (p<0.05)	**NS**	**NS**	**0.37**	**NS**

Table 4.2. Days to 50% head formation and days to 50% head maturity in different planting dates

Planting dates	**Days to 50% head formation**	**Days to 50% head maturity**
May 15th	48.00	68.00
May 30th	47.90	63.75
June 15th	55.50	70.75
June 30th	59.00	75.50
July 15th	59.00	73.25
July 30th	54.25	67.00
Mean	**53.94**	**69.71**
CD(p<0.05)	**4.97**	**4.93**

4.1.7. Gross head weight

Significant difference was noticed between planting dates with regard to gross head weight. The maximum gross head weight was observed in May 15th (1345 g) planting followed by July 15th (1248.75 g), July 30th (1181.25 g), June 30th (1100 g), May 30th (1075 g) and June 15th (907.50 g) planting (Table 4.3). The treatments May 30th, June 15th and June 30th were found to be on par. The minimum gross head weight of 907.50 g was recorded by June 15th planting.

4.1.8. Net head weight

Net head weight was significantly influenced by planting dates and the maximum net head weight was recorded for May 15th (818.75 g) planting which was on par with July 15th (700 g) and July 30th (661.25 g) planting. The minimum net head weight was recorded by June 15th (486.25 g). The mean net head weight was 646.04 g (Table 4.3).

4.1.9. Head length

There was significant difference between planting dates with respect to head length. The maximum head length was observed for May 15th (13.55 cm) planting which was on par with June 30th (12.91 cm) and July 15th (12.73 cm) planting. The minimum head length was noticed for June 15th (11.85 cm) planting which was on par with July 30th (12.50 cm) planting. The mean head length observed was 12.70 cm (Table 4.4).

4.1.10. Head breadth

There was significant difference between planting dates with regard to head breadth. The maximum head breadth was observed for May 15th (15.73 cm) planting which was on par with July 15th (15.08 cm) and June 30th (14.59 cm) planting. The minimum head breadth was noticed for June 15th (12.83 cm) planting which was on

par with May 30th (13.95 cm) planting. The mean head breadth observed was 14.39 cm (Table 4.4).

4.1.11. Core length

There was no significant difference between planting dates with respect to core length. The maximum core length was observed for July 15th (7.93 cm) planting and the minimum was observed for June 15th (7.08 cm) planting. The mean core length observed was 7.62 cm (Table 4.4).

4.1.12. Head index

There was no significant difference between planting dates with regard to head index. The treatment June 15th recorded the highest head index value of 0.92 and the least value for head index was recorded by July 15th (0.85) planting. The mean head index was 0.89 (Table 4.4).

4.1.13. Harvest index

The dates of planting significantly influenced the harvest index. The highest harvest index was recorded for May 15th (60.79) planting and the lowest was recorded for June 15th (53.05) planting. The treatments May 30th (55.60), June 15th (53.05), June 30th (55.11), July 15th (56.05) and July 30th (55.82) were on par with regard to harvest index (Table 4.3).

4.1.14. Total number of marketable heads

The planting dates did not differ significantly for total number of marketable heads. Out of twenty plants in a plot, May 15th planting recorded the maximum number of marketable heads (16.75) followed by July 15th (16.25), June 15th (15.75), June 30th (14.75), May 30th (13.75) and July 30th (13.25) planting. The average number of marketable heads was 15.08 (Table 4.5). The unmarketable heads are shown in Plate 6.

Table 4.3. Gross head weight, net head weight and harvest index in different planting dates

Planting dates	Gross head weight (g)	Net head weight (g)	Harvest index (%)
May 15th	1345.00	818.75	60.79
May 30th	1075.00	602.50	55.60
June 15th	907.50	486.25	53.05
June 30th	1100.00	607.50	55.11
July 15th	1248.75	700.00	56.05
July 30th	1181.25	661.25	55.82
Mean	**1142.92**	**646.04**	**56.07**
CD (p<0.05)	**226.83**	**159.61**	**4.35**

Table 4.4. Head length, head breadth, head index and core length in different planting dates

Planting dates	Head length (cm)	Head breadth (cm)	Head index	Core length (cm)
May 15th	13.55	15.73	0.86	7.91
May 30th	12.65	13.95	0.91	7.73
June 15th	11.85	12.83	0.92	7.08
June 30th	12.91	14.59	0.89	7.79
July 15th	12.73	15.08	0.85	7.93
July 30th	12.50	14.18	0.89	7.28
Mean	**12.70**	**14.39**	**0.89**	**7.62**
CD(p<0.05)	**0.89**	**1.34**	**NS**	**NS**

4.1.15. Yield/plot

Yield/plot was significantly influenced by planting dates. The highest yield/plot (area 5.4 m^2) was observed for May 15th (11.78 kg) planting which was on par with July 15th (9.36 kg) planting. The lowest yield/plot was recorded for June 15th (6.13 kg) planting. The mean yield/plot was 8.32 kg (Table 4.6).

4.1.16. Moisture content

There was significant difference among planting dates with respect to moisture content. The maximum moisture content was observed for July 15th (94.69 %) planting which was on par with June 30th (94.62 %) and July 30th (94.13 %) planting. The minimum moisture content was observed for June 15th (93.41 %) which was on par with May 30th (93.83 %) and May 15th (93.78 %) planting. The mean moisture content was 94.08 % (Table 4.7).

4.2. QUALITATIVE CHARACTERS

4.2.1. Head shape

There was no difference in head shape during all the planting dates (Table 4.8). The head shape of cabbages in all the dates of planting was round (Plate 7.).

4.2.2. Head compactness

There was no pronounced difference in head compactness among plants transplanted on different dates (Plate 8.). Heads were classified as loose though slight variations were observed within treatments for all planting dates with respect to head compactness (Table 4.8).

Table 4.5. Total number of marketable heads obtained in different planting dates

Planting dates	**Total number of marketable heads**
May 15th	16.75
May 30th	13.75
June 15th	15.75
June 30th	14.75
July 15th	16.25
July 30th	13.25
Mean	**15.08**
CD(p<0.05)	**NS**

Table 4.6. Yield/plot obtained in different planting dates

Planting dates	**Yield/plot (kg)**
May 15th	11.78
May 30th	7.05
June 15th	6.13
June 30th	7.66
July 15th	9.36
July 30th	7.96
Mean	**8.32**
CD (p<0.05)	**2.66**

Table 4.7. Moisture content of cabbage in different planting dates

Planting dates	**Moisture content (%)**
May 15th	93.78
May 30th	93.83
June 15th	93.41
June 30th	94.62
July 15th	94.69
July 30th	94.13
Mean	**94.08**
CD (p<0.05)	**0.56**

Table 4.8. Head shape and head compactness in different planting dates

Planting dates	**Head shape**	**Head compactness**
May 15th	Round	Loose
May 30th	Round	Loose
June 15th	Round	Loose
June 30th	Round	Loose
July 15th	Round	Loose
July 30th	Round	Loose

Plate 6. Unmarketable heads

Plate 7. Head shape of cabbage (Round)

4.3. PEST AND DISEASE INCIDENCE

4.3.1. Pest incidence

The major pest observed during all the planting dates was tobacco caterpillar (*Spodoptera litura* F.) (Plate 9.). Severe feeding of cabbage heads by the caterpillar lead to completely unmarketable heads. Apart from the incidence of tobacco caterpillar, there was slight incidence of slugs and snails. The lowest percentage of plants affected by pests was observed in May 15th (8.75 %) planting followed by July 15th (10 %), June 15th (11.25 %), May 30th (13.75 %), June 30th (16.25 %) and July 30th (23.75 %) planting. The percentage of plants affected by pests is shown in Table 4.9.

4.3.2. Disease incidence

There was no major incidence of any diseases in any of the treatments. Soft rot (caused by *Erwinia carotovora*) was observed (Plate 10.) in all treatments which may be due to primary attack by *Spodoptera litura* F. The soft rot affected heads were completely unmarketable. The lowest percentage of plants affected by the disease was observed in May 15th (3.75 %) planting followed by July 30th (7.50 %), July 15th (8.75 %), May 30th (10 %), June 15th (10 %) and June 30th (11.25 %) planting. The percentage of plants affected by the disease is shown in Table 4.9.

Internal tip burn, a physiological disorder generally considered to be caused due to calcium deficiency was noticed in all treatments which affected the quality of heads (Plate 11.). The disorder was characterized by necrosis at the margins of young developing leaves in the inner part of heads. The affected heads showed no external symptoms and therefore could not be detected from field unless heads are severed.

Plate 8. Head compactness (Loose)

Plate 9. Tobacco caterpillar attack on plant

Plate 10. Soft rot in cabbage

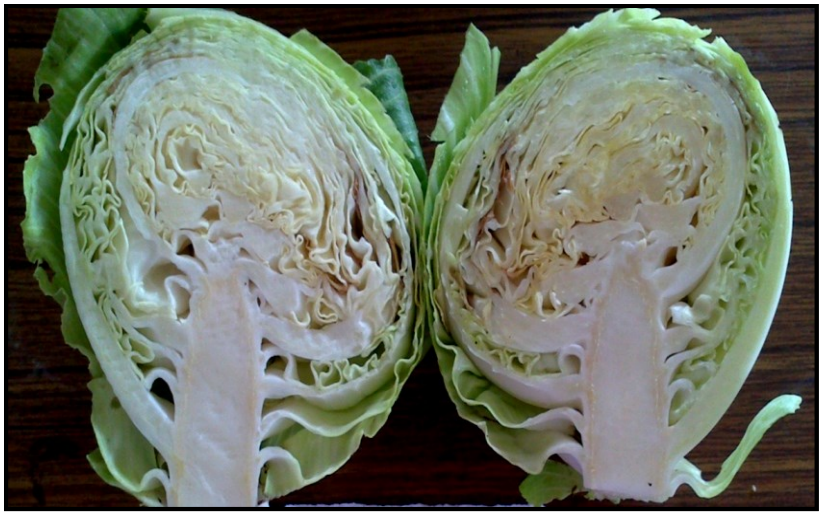

Plate 11. Internal tip burn affected head

4.4. BENEFIT-COST RATIO

The total cost of cultivation was recorded as Rs. 62.70 per m^2 whereas the total benefit varied from Rs. 41.73 to Rs. 75.21 per m^2 in different dates of planting (Table 4.10). The highest benefit-cost ratio of 1.2 was obtained for May 15th planting whereas the lowest was obtained for May 30th planting (0.67). Construction and maintenance of the structure accounted 47.84% of the total cost whereas labour occupied 42.58% of the total cost.

Table 4.9. Percentage of plants affected by pest and disease in different planting dates

Planting dates	Pest incidence (%)	Disease incidence (%)
May 15th	8.75	3.75
May 30th	13.75	10.00
June 15th	11.25	10.00
June 30th	16.25	11.25
July 15th	10.00	8.75
July 30th	23.75	7.50

Table 4.10. Economics of cultivation in different dates of planting

Planting dates	Harvest date	Price of cabbage/kg (Rs.)	Total cost/m^2 (Rs.)	Yield/m^2 (kg)	Total benefit/m^2 (Rs.)	Benefit cost ratio
May 15th	18/7/13	34.19	62.7	2.2	75.21	1.20
May 30th	2/8/13	32.10	62.7	1.3	41.73	0.67
June 15th	16/8/13	40.62	62.7	1.1	44.68	0.71
June 30th	6/9/13	36.02	62.7	1.4	50.42	0.80
July 15th	24/9/13	32.05	62.7	1.7	54.48	0.87
July 30th	3/10/13	30.00	62.7	1.5	45.00	0.72

DISCUSSION

5. DISCUSSION

Cabbage is an important cole crop, which is cultivated under temperate to tropical conditions for its head. Its cultivation during winter season has gained popularity in the plains of Kerala. But cabbage cultivation in open condition during off-season (rainy season) is not possible as heavy monsoon downpour leads to poor or no head formation (Malu, 2011). High plant mortality renders the monsoon cultivation of cabbage unprofitable eventhough the sale price of cabbage heads is high. To overcome the problem of high plant mortality and guarantee a successful crop, one possible approach would be to manipulate the time of transplanting.

The yield of cabbage is significantly affected by both cultivars and transplanting dates (Singh *et al*., 2010). Hence selection of suitable genotype with an appropriate planting date is an important step towards achieving high yield in protected cultivation. Since cost per unit area in protected cultivation is high, hybrids having high yielding ability (Sharma and Sharma, 2001) are to be used for attaining high yield per unit area which in turn will increase the returns. The present study entitled "Standardization of planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata)* production in rain shelter" was endeavored to identify the ideal planting time for off-season cabbage production in rain shelter.

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

5.1. Influence of planting dates on quantitative characters

5.2. Influence of planting dates on qualitative characters

5.3. Influence of planting dates on pest and disease incidence

5.4. Economics of cultivation

5.1. INFLUENCE OF PLANTING DATES ON QUANTITATIVE CHARACTERS

5.1.1. Plant spread

Plant spread is the average distance between two outer leaves of a cabbage plant. Chaubey *et al.* (2006) reported that smaller plant spread is preferable since it allows greater plant population per unit area. According to Singh *et al*., (2010), plant spread had significant positive correlation with gross plant weight, head length, head breadth, core length and net head weight. Suseela (2002) reported that the yield in cauliflower increased with increase in plant spread up to 82 cm after which a substantial reduction in yield was noticed. In the present study, it was observed that there was no significant difference between planting dates with respect to plant spread. However the maximum plant spread (59.90 cm) was recorded in May 30th planting and the minimum (56.93 cm) was recorded in June 30th planting. The mean plant spread was 58.45 cm.

Major long term effect of humidity in greenhouse crops is through its effect on leaf area and humidity favours leaf expansion. Srihari and Satyanarayana (1992) observed that leaf size had direct effect on plant spread. Malu (2011) reported that plant spread in cabbage is less in off-season when compared to on-season. She also noticed that during off-season, plant spread is higher for rain shelter crop when compared to open field crop.

5.1.2. Number of non wrapping leaves

Non wrapping leaves are the leaves that do not cover the head portion. Lesser number of non wrapping leaves is a desirable character for cabbage genotypes (Sharma *et al*., 2006). In the present study no significant difference was observed between planting dates with respect to the number of non wrapping leaves. The minimum number of non wrapping leaves (7.15) was observed for May 30th planting and the maximum number of non wrapping leaves (8.35) was found for June 15th

planting. Malu (2011) recorded a value of 7.4 for this character for the cultivar NS 43 during off-season.

5.1.3. Number of wrapping leaves

Wrapping leaves are the leaves that cover the head portion of cabbage. There was significant difference between planting dates with respect to the number of wrapping leaves. The maximum number of wrapping leaves (6.15) was observed for June 30th (Fig 5.1) planting. The minimum number of wrapping leaves was recorded in May 30th planting (3.9) which was on par with May 15th planting (4.0). Similar result was obtained by Malu (2011) for the same character during off-season.

5.1.4. Stalk length

Stalk length is the distance from ground level to the first non wrapping leaves. Shorter stalk length is one among the desirable characters of most ideal and commercially acceptable cabbage genotypes (Sharma *et al*., 2006). In the present study it was observed that planting dates had no significant effect on stalk length. However the highest value for stalk length was observed for May 30th (3.45 cm) planting and the least was recorded for June 30th (2.64 cm) planting. Pradeepkumar *et al*. (2002) reported that early planting in cauliflower induced production of short stalks in the open field.

5.1.5. Days to 50% head formation

The number of days from transplanting to the date when at least 50% of the plants attain head formation is considered as the days to 50% head formation. There was significant difference among planting dates with regard to days to 50% head formation (Fig 5.2). May 30th planted ones were the earliest (47.9 days) to achieve 50% head formation while June 30th and July 15th planted ones took the maximum number of 59 days to achieve 50% head formation. However, mean number of days to achieve 50% head formation was observed to be 53.94 days which is in

confirmation with the results of study conducted by Malu (2011) in which the same hybrid under study NS 43, in off-season took 52 days to achieve 50% head formation inside rain shelter. Prevalence of favourable weather conditions inside rain shelter during off-season similar to that of on-season would have resulted in 100 per cent head formation in all planting dates.

According to Malu (2011), relative humidity values obtained from rain shelter during off-season was in range with those of the on-season crop consequently providing the rain shelter crop with favorable conditions for head formation during off-season. She also reported that days to 50% head formation was positively correlated with maximum temperature and morning relative humidity while it showed negative correlation with minimum temperature and relative humidity at noon.

5.1.6. Days to 50% head maturity

Attainment of maximum head size is considered as an index of cabbage maturity (Isenberg *et al*., 1975). The treatments showed significant difference with respect to 50% head maturity which is recorded as the number of days from transplanting to the date when at least 50% of the plants produced marketable heads. The minimum number of days to achieve 50% head maturity was observed for May 30th (63.75 days) planting which was on par with May 15th (68 days) planting and the maximum days to obtain 50% head maturity was observed for June 30th (75.50 days) planting (Fig 5.2).

Malu (2011) observed that NS 43 during off-season inside rain shelter achieved 50% head maturity 74.5 days after transplanting. Whereas Nakkande (2013) obtained 50% head maturity for the same hybrid in open condition during on-season 49 to 53 days after transplanting. Chaubey *et al.* (2006) reported that the reason for early maturity could be the prevailing high temperature, which forced the crop to accomplish its vegetative growth and thereby heading early. In the present study also early planting resulted in early head formation and head maturity.

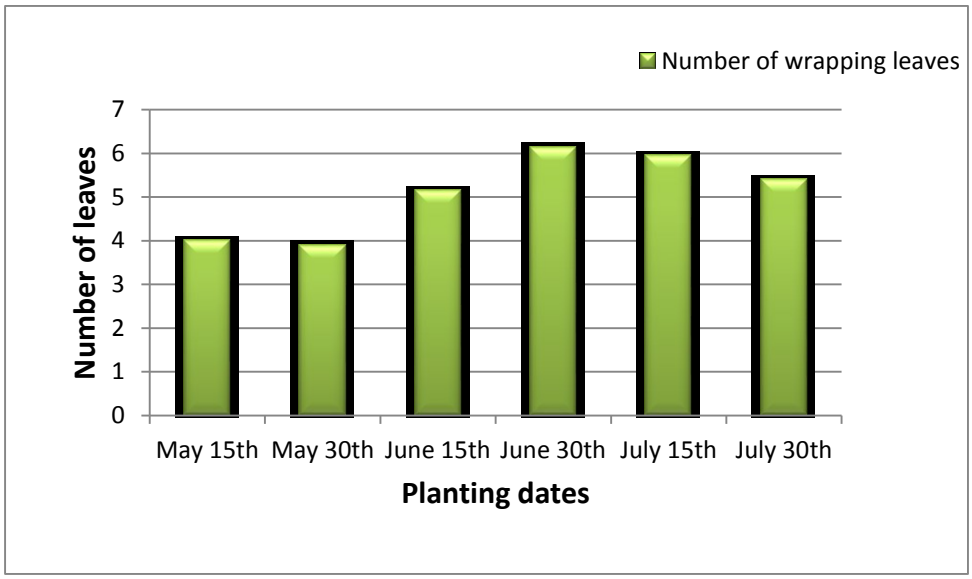

Fig 5.1 Effect of planting dates on number of wrapping leaves

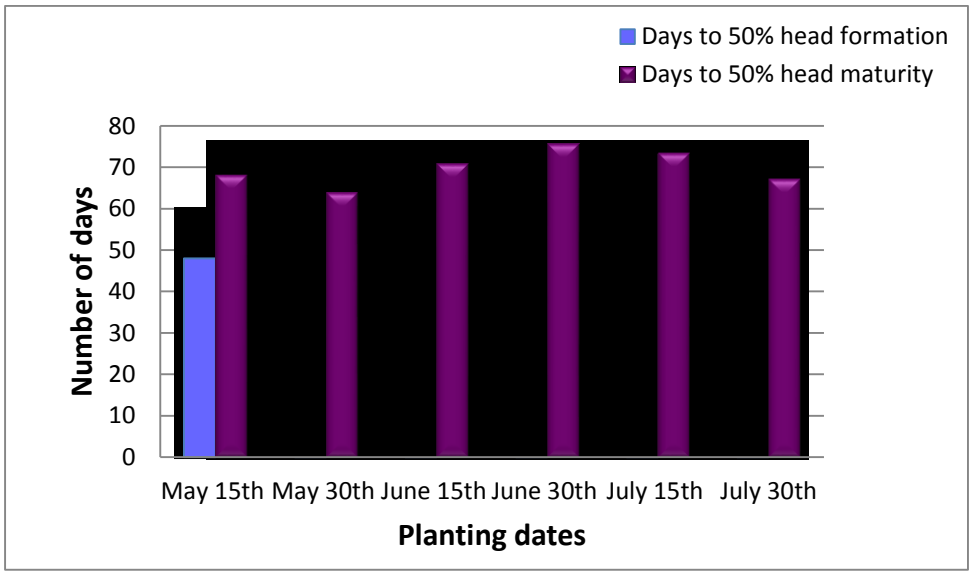

Fig 5.2 Effect of planting dates on days to 50% head formation and days to 50% head maturity

5.1.7. Gross head weight

Gross head weight is the weight of head along with non wrapping leaves and stalk which is recorded at marketable stage. Significant difference was noticed between planting dates with regard to gross head weight. The maximum gross head weight was observed in May 15th (1345 g) planting and the minimum was observed for June 15th (907.50 g) planting (Fig 5.3). It can be concluded that early planting resulted in maximum vegetative growth. This is in confirmation with results obtained by Pradeepkumar *et al*. (2002) in a study conducted with cauliflower in which largest net weight, gross weight and total yield were obtained with early planting. Suseela (2002) observed that cauliflower plant exhibited maximum vegetative growth during the initiation of curd and declined thereafter towards harvest.

5.1.8. Net head weight

The weight of individual heads is observed as the net head weight. The date of transplanting significantly influenced the net head weight in cabbage (Singh *et al*., 2010) and cauliflower (Karthika *et al*., 2013) which shows the influence of environments on growth and yield of these crops. In the present study also it was found that net head weight was significantly influenced by planting dates and the maximum net head weight was recorded by early planting ie., for May 15th (818.75 g) planting (Fig. 5.3). Similar values were recorded by Bhatt *et al*. (2008) for cabbage hybrid S-990 when grown in mid hills of Uttarakhand during off-season under open condition and Elavarasan (2011) for NS 183 during on-season in the plains of Kerala. The minimum net head weight was recorded in June 15th (486.25 g) planting which would possibly be due to unfavorable weather condition experienced by the crop during its head formation stage.

In the present study, the net head weight ranged from 486.25 g to 818.75 g. The weather condition prevailing during the various growth stages of the crop would have affected the net head weight. The average head weight depended mostly on

climatic conditions during the growing season (Staugaitis *et al*., 2004). Malu (2011) reported that during off-season in rain shelter, the hybrid NS 43 recorded a net head weight of 553.5 g whereas during the on-season, the same hybrid recorded a higher net head weight of 945.5 g. According to Theodore *et al*. (2004), air temperature influences the terminal size and weight of mature heads. He also noticed that changes in head size and head weight correlate strongly with thermal time.

From the values of gross head weight and net head weight recorded in the present study, it can be concluded that higher the gross weight higher is the net head weight.

5.1.9. Head length

Head length is a measurement of head index which in turn determines the shape of cabbage head. Head length is the polar diameter of head at marketable stage. In this study, it was observed that planting dates significantly influenced the head length. The maximum head length was observed for May 15th (13.55 cm) planting which was on par with June 30th (12.91 cm) and July 15th (12.73 cm) planting while the minimum head length was noticed for June 15th (11.85 cm) planting (Fig 5.4). The mean head length was observed to be 12.70 cm. Head length within this range was reported by Elavarasan (2011) with different cabbage cultivars when grown in hilly area of Kerala and by Malu (2011) for the same hybrid during off-season.

5.1.10. Head breadth

Head breadth or equatorial diameter of head is recorded at marketable stage. In the current study, significant difference was observed between planting dates with regard to head breadth (Fig 5.4). The maximum head breadth was observed for May 15th (15.73 cm) planting which was on par with July 15th (15.08 cm) and June 30th (14.59 cm) planting. The minimum head breadth was noticed for June 15th (12.83 cm)

planting which was on par with May 30th (13.95 cm) planting. The mean head breadth was observed to be 14.39 cm which was similar to results of Malu (2011).

5.1.11. Core length

Core length is measured as the length of the core region of marketable heads. According to Kleinhenz and Wszelaki (2003), as heads develop, a decrease in percentage head volume occupied by the core results in more utilizable product available to processors and consumers. He also reported that a short core less than 25 percent of head diameter is generally desirable. In the current study, no significant difference was observed between planting dates with respect to core length. The maximum core length was observed for July 15th (7.93 cm) planting and the minimum was observed for June 15th (7.08 cm) planting. Similar values were reported by Malu (2011).

5.1.12. Head index

Head index is calculated as the ratio of head length or polar diameter to head breadth or equatorial diameter at marketable stage. From the value of head index, the head shape could be predicted. There was no significant difference between planting dates with regard to head index. The treatment June 15th recorded the highest head index value of 0.92 and the least value for head index was recorded by July 15th (0.85) planting. The mean head index was observed to be 0.89. The cabbage genotypes with head shape index (0.8-1) are preferred and they have round shape (Sharma *et al*., 2006).

It was observed that the planting date with the highest head index (0.93) gave the lowest net head weight (486.25 g). Singh *et al*. (2010) reported that head shape index had negative correlation with net head weight. This implies that round head type plants or genotypes would produce cabbage heads with lower net head weight when compared to flat or drum head ones.

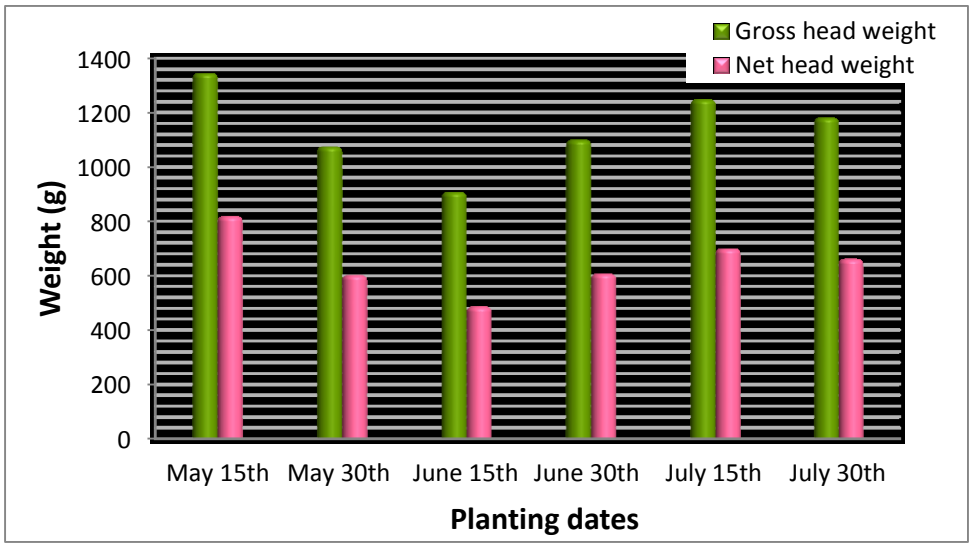

Fig 5.3 Effect of planting dates on gross head weight and net head weight

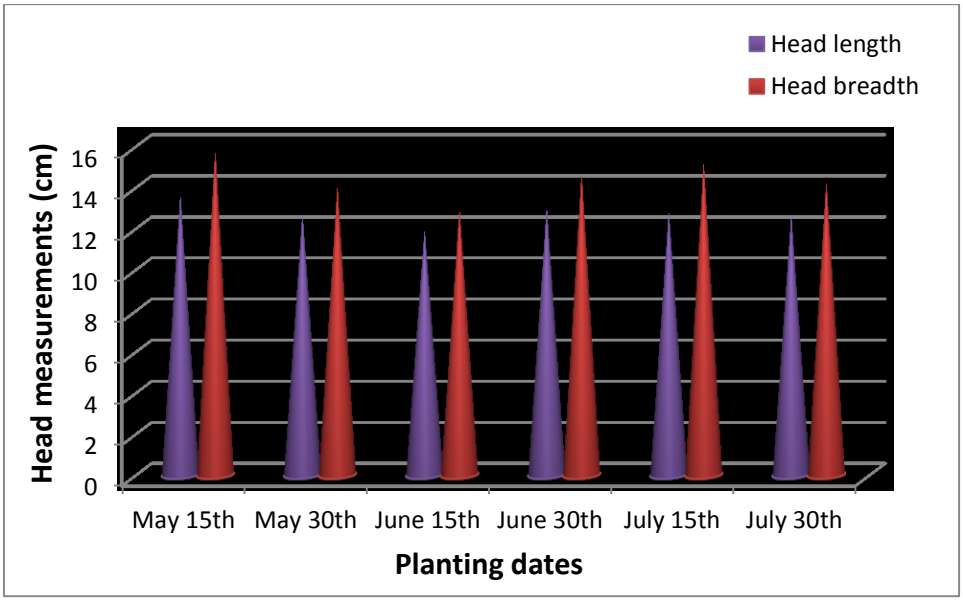

Fig 5.4 Effect of planting dates on head length and head breadth

5.1.13. Harvest index

Harvest index was significantly influenced by the dates of planting. It is the ratio of net head weight (economic yield) to gross head weight (biological yield). Harvest index is a yield attribute which is found to have a direct relationship with yield (Sharma *et al*., 2006). This finding is in line with the current study. The harvest index was found significantly higher in May 15th (60.79) planting as compared to other dates of planting (Fig 5.5), which was the treatment that recorded the highest net head weight. The lowest value for harvest index (53.05) was observed for the treatment that recorded the lowest net head weight (June 15th).

5.1.14. Total number of marketable heads

The harvested heads obtained from each plot were sorted into marketable and unmarketable (very small, rotten and damaged heads) based on visual observation. The number of marketable heads from each plot comprising of twenty plants was recorded as the total number of marketable heads. It was observed that the planting dates did not differ significantly for total number of marketable heads. However, the maximum number of marketable heads was observed in May 15th (16.75) planting which was due to the low pest and disease incidence. The lowest number of marketable heads was recorded for July 30th (13.25) planting which was due to high pest incidence. The average number of marketable heads was 15.08 which imply that approximately 75% of the heads harvested per plot was marketable. Similar result was reported by Malu (2011) for the cabbage hybrid Disha during on-season inside rain shelter.

5.1.15. Yield/plot

Yield/plot is the total net head weight of all the marketable heads from each plot (area 5.4 m^2). Elavarasan (2011) reported that planting date and season had an effect on total and marketable yield in cabbage. In the present study it was noticed

that planting dates had significantly influenced the yield/plot. The highest yield/plot was observed for May 15th (11.78 kg) planting (Fig 5.6) which means that by off-season cultivation of NS 43 inside rain shelter, an approximate yield of 22 tonnes/ha can be achieved. This yield is comparable with the current national productivity of cabbage which is 22.9 tonnes/ha (NHB, 2014). The lowest yield/plot was recorded for June 15th (6.13 kg) planting which is due to low net head weight. The mean yield/plot was 8.32 kg.

Elavarasan (2011) reported that yield was less for cabbage genotypes cultivated in plains which was apparently due to the unfavorable weather condition that prevailed during the growing season.

5.1.16. Moisture content

Moisture content is an indicator of the dry matter content. Higher the moisture content, lower will be the dry matter and vice versa. According to Mirecki (2012), the date of planting influenced dry matter content in cabbage as well as Brussels sprouts. Planting time has significant effect on moisture content in cabbage (Ullah *et al.*, 2013). In the present study also it was found that planting dates significantly influenced the moisture content in cabbage. The maximum moisture content was observed for July 15th (94.69 %) planting which was on par with June 30th (94.62 %) and July 30th (94.13 %) planting. The minimum moisture content was observed for June 15th (93.41 %) planting which was on par with May 30th (93.83 %) and May 15th (93.78 %) planting. This reveals the fact that late planting leads to an increase in moisture content (Fig 5.7).

According to Chakrabarti (2001), the moisture content in cabbage is 92.4 %. In the present study, the mean moisture content was 94.08 % which is higher than that reported by Elavarasan (2011) in cabbage genotype Tropical Sun Plus (90.59 %) when grown in the plains of Kerala during on-season. Hence it can be concluded that

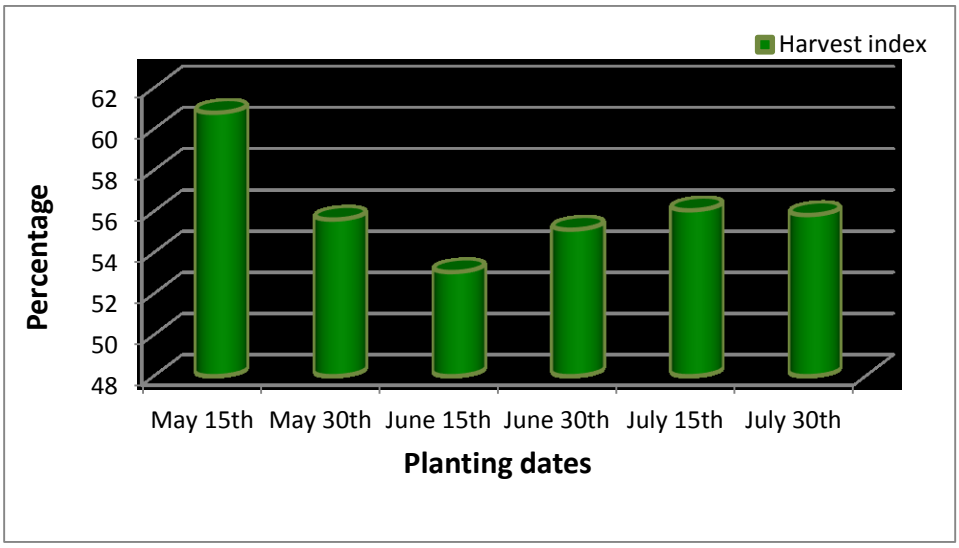

Fig 5.5 Effect of planting dates on harvest index

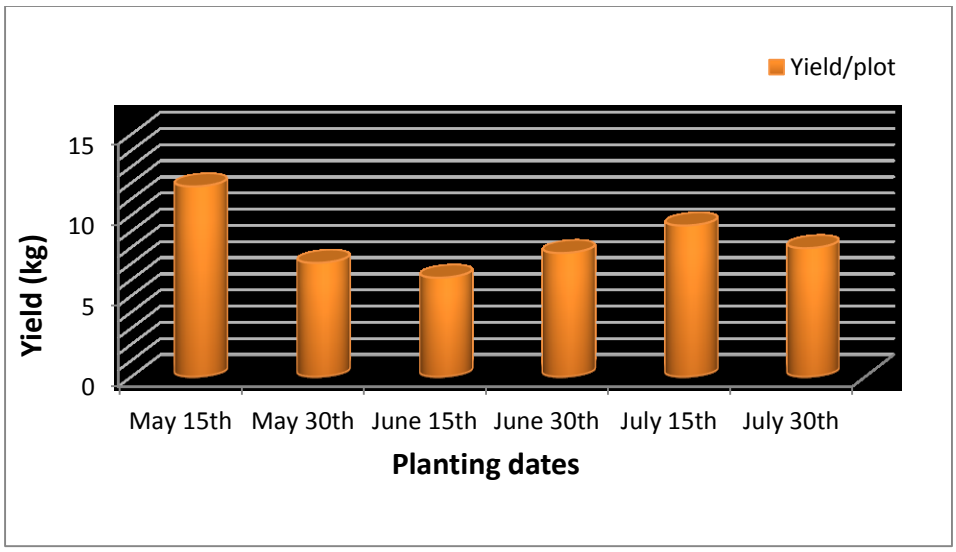

Fig 5.6 Effect of planting dates on yield/plot

moisture content in cabbage is higher during rainy season (off-season) when compared to winter season (on-season).

5.2. INFLUENCE OF PLANTING DATES ON QUALITATIVE CHARACTERS

5.2.1. Head shape

Planting time has an influence on head shape in cabbage (Tewari *et al.,* 1977). In the present study, there was no major difference in head shape during all the planting dates. According to Ram (1997), the shape of cabbage head is usually expressed in terms of polar and equatorial diameters and these ratios are 0.8 to 1.0 for spherical head, 0.6 or less for drum head and more than 1.0 for conical head. On analyzing the head index values obtained, which was found to be within the range of 0.85-0.92, it can be clearly stated that the head shape in cabbages belonging to all the planting dates was round.

This is in contrary to the finding by Malu (2011), in which the hybrid NS 43 invariably produced flat or drum head shaped heads when raised under rain shelter during both on and off- season. Nakkande (2013) also reported flat head shape for the same hybrid when grown in open field during on-season.

The round shape cultivar have preference over semi round cultivar due to its attractiveness (Bhatt *et al*., 2008). Temperature has significant effect on cabbage head shape (Sundstrom and Story, 1984). According to Kleinhenz and Wszelaki (2003), head shape is a result of cumulative environmental conditions and the conditions that prevailing earlier on the plant and crop development may have a stronger influence on the same.

5.2.2. Head compactness

Head compactness which is directly associated with the transportability, marketability, shelf-life and consumer preference is an important quality trait in

cabbage (Singh *et* al., 2010). There was no pronounced difference in head compactness among plants transplanted on different dates. All the heads could be categorized as loose though slight variations were noticed within treatments for all planting dates. NS 43 formed compact heads inside rain shelter during off-season (Malu, 2011). According to DuhSukh (1999), Chinese cabbage heads formed under high temperature showed poor compactness and low contents of soluble solids due to the high respiration rate. Singh *et al.* (2010) reported that head compactness is having a negative correlation with gross weight and plant spread.

5.3. INFLUENCE OF PLANTING DATES ON PEST AND DISEASE INCIDENCE

5.3.1. Pest incidence

Chari and Patel (1983) reported that among the different pests infesting cabbage, *Spodoptera litura* F. is the most important polyphagous pests distributed throughout the south eastern region in the world. In the present study under the climatic conditions of Kerala, the major pest observed during all the planting dates was tobacco caterpillar (*Spodoptera litura* F.). Its incidence was observed in all stages of the crop. Severe feeding of head by the caterpillar lead to completely un marketable heads. Malu (2011) also reported *Spodoptera litura* F. as the major pest of cabbage during off-season.

Slight incidence of slugs and snails were also observed. Slug damage to Chinese and spring cabbage was found to increase after rain (Munden and Bailey, 1989). In the present study, the lowest percentage of plants affected by pests was observed in May 15th (8.75 %) planting whereas the highest percentage was observed in July 30th (23.75 %) planting (Fig 5.8). Increased number of rainy days and decreased rainfall increased the population of *S. litura* F. on cabbage during rainy season (Patait *et al*., 2008).

5.3.2. Disease incidence

According to Kuo and Tsay (1981), tip burn and soft rot are the major problems that are often encountered by Chinese cabbage when grown at high temperatures. In the present study also, tip burn and soft rot were the problems for off-season crop inside rain shelter.

There was no major incidence of any diseases in any of the treatments. Soft rot (caused by *Erwinia carotovora*) was observed in all treatments which may be due to primary attack by *Spodoptera litura* F. Soft rot (*Erwinia carotovora* sub sp. carotovora) is one of the destructive diseases of vegetables including cabbage worldwide (Bhat *et al.,* 2010). The soft rot affected heads were completely unmarketable. The lowest percentage of plants affected by the disease was observed in May 15th (3.75 %) planting and the highest was recorded in June 30th (11.25 %) planting (Fig 5.8).

A physiological disorder called internal tip burn was noticed in all planting dates which was observed as necrosis at the margins of young developing leaves inside cabbage heads. Calcium deficiency is often considered as the major cause of tip burn disorder which can cause serious economic losses (Saure, 1998). According to Beckar and Bjorkman (1986), this disorder can be caused by a lack of calcium in the soil, but more often it results from the plant's inability to move sufficient calcium to the young, actively growing, inner head leaves at a critical point of their development.

Crop transpiration rate which maintains the leaf and canopy temperature plays an important role in green houses. It has been reported that generally during morning hours, the humidity inside the green house increases and affects the transpiration rate of plant. The increased humidity reduces the transpiration rate and this could cause calcium deficiency in the plants inside the green house which impact the leaf

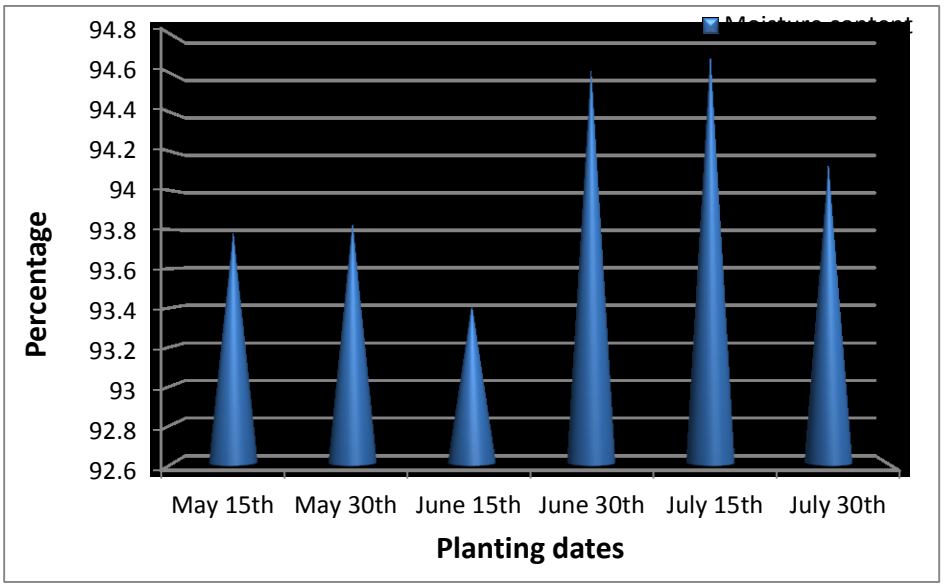

Fig 5.7 Effect of planting dates on moisture content in cabbage

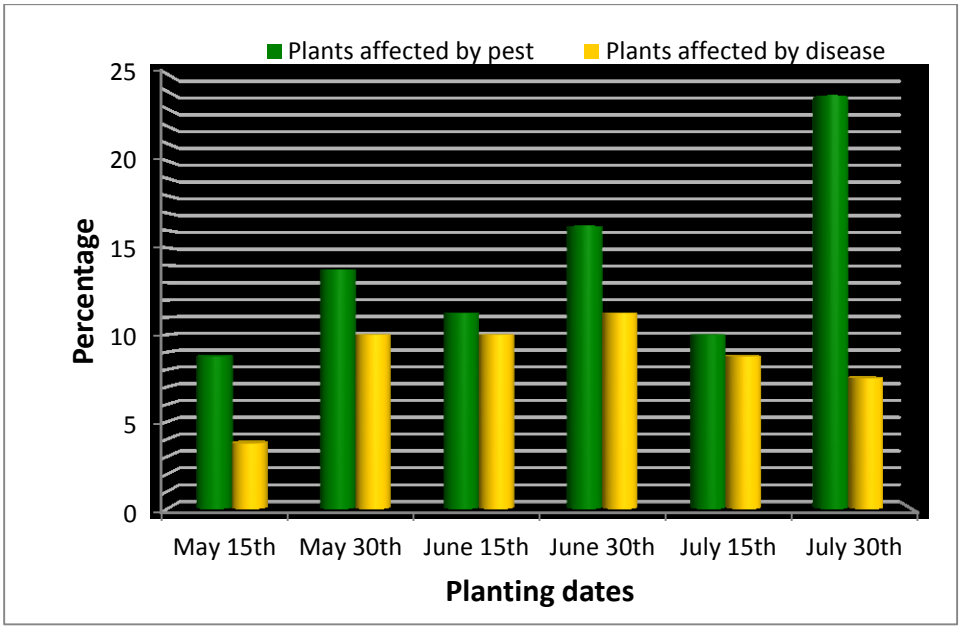

Fig 5.8 Effect of planting dates on percentage of plants affected by pest and disease

development. According to Malu (2011), the morning relative humidity inside the rain shelter during rainy season is higher than that of on-season.

Calcium being immobile in the plant, its deficiency symptoms is shown up first on young growing leaves which are the internal leaves of the head. As a result of this, margins of the inner leaves turn brown and desiccate to become thin and papery at the margins or over large portions of the leaf. The affected tissue may turn brown to black thus affecting the visual appeal of the head when cut open. As this happens in the internal leaves of the head, the disorder remain undetected till the head is cut for consumption.

Sometimes the tip burn affected tissue is invaded by secondary organisms that cause soft rot (Beckar and Bjorkman, 1986). Hence apart from the attack by *Spodoptera litura* F. on cabbage heads, tip burn could also be a probable reason for the occurrence of soft rot which was observed in the present study. Since the calcium is fixed by the outer leaves and not further translocated to the young growing leaves, neither soil nor foliar application of calcium will be effective in alleviating tip burn (Rana, 2008). Susceptibility to tip burn is genetically determined (Maynard and Barker, 1972) and the use of resistant cultivar is the possible way to reduce the incidence of this disorder (Rana, 2008).

5.4. ECONOMICS OF CULTIVATION

The total cost of cultivation was Rs. 62.70 per m^2 whereas the total benefit varied from Rs. 41.73 to Rs. 75.21 per m^2 in different dates of planting. Construction and maintenance of the structure accounted 47.84% of the total cost whereas cost of labour occupied 42.58% of the total cost. The contribution to total cost of cultivation of off-season cabbage in Shimla by human labour was 43.3 % (Pandey *et al.,* 2001).

The highest benefit-cost ratio of 1.2 was obtained for May 15th planting whereas the lowest was obtained for May 30th planting (0.67). Malu (2011) obtained

a benefit cost ratio of 1.14 for rain shelter crop of cabbage during off-season. Though the highest price per kg was recorded at the time of harvest of June 15th planting, the highest benefit-cost ratio was obtained in May 15th planting due to high yield. This implies that May 15th planting is profitable though price of cabbage is less at the time of its harvest.

Even though the benefit is on par, the advantage is that an additional crop of cabbage can be obtained during rainy season inside rain shelter. By adopting proper plant protection measures and selecting disease resistant and high yielding tropical hybrids, the yield can be increased. Labour cost can be reduced by utilizing the family labour and resorting to precision farming. Thus benefit-cost ratio can be increased and many of the literate unemployed youth can take this protected cultivation as a self employment programme.

SUMMARY

6. SUMMARY

A study was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during the rainy season (May-October) of the year 2013 with the objective to standardize the planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata*) production in rain shelter. The experiment was laid out in Randomized Block Design with four replications. The treatments comprised six planting dates namely May 15th, May 30th, June 15th, June 30th, July 15th and July 30th. The cabbage hybrid NS 43 was used in the study.

Observations on quantitative and qualitative characters of cabbage were made during the course of study. The data were statistically analyzed and the salient findings of the study are summarized below.

- Head formation was noticed in all dates of planting eventhough rainy season is an off-season for cabbage.
- There was no significant difference between planting dates with respect to plant spread, number of non wrapping leaves, stalk length, core length, head index and total number of marketable heads.
- The lowest number of wrapping leaves was observed for May 30th (3.9) planting which was on par with May 15th (4.0) planting.
- May 30th planting took the minimum number of days to reach 50% head formation (47.9 days) which was on par with May 15th (48 days) planting.
- The minimum number of days to reach 50% head maturity was observed for May 30th (63.75 days) planting which was on par with May 15th (68 days) and July 30th (67 days) planting.
- The highest net head weight was observed in May 15th (818.75 g) planting whereas the lowest was recorded in June 15th (486.25 g) planting.

- May 15th planting recorded the maximum value for head characters like head length (13.55 cm) and head breadth (15.73 cm).
- The highest harvest index was observed in May 15th (60.79) planting while the lowest harvest index was observed in June 15th (53.05) planting.
- The highest yield/plot was observed for May 15th (11.78 kg) planting which was on par with July 15th (9.36 kg) planting.
- The minimum moisture content was observed for June 15th (93.41 %) planting which was on par with May 30th (93.83 %) and May 15th (93.78 %) planting.
- The head shape of cabbages of all the planting dates was round.
- With respect to head compactness, heads in all planting dates were found to be loose.
- The major pest observed during all the planting dates was tobacco caterpillar (*Spodoptera litura* F.).
- Incidence of soft rot (*Erwinia carotovora*) was noticed in all dates of planting.
- A physiological disorder called internal tip burn reported to be caused due to calcium deficiency was noticed in heads in all planting dates.
- The lowest pest and disease incidence was observed for May 15th planting.
- The highest benefit-cost ratio was obtained for May 15th (1.2) planting.
- Considering the yield and lower pest and disease incidence, May 15th planting was found ideal for off-season cultivation of cabbage inside rain shelter.

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APPENDICES

APPENDIX I

Weather data during off-season (May - October, 2013) in open condition:

Period	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (morning) %	Relative humidity (noon) %	Rainfall (mm)
14/5/13-20/5/13	34.4	25.1	89	55	6.4
21/5/13-27/5/13	34.0	24.6	92	61	5.7
28/5/13-3/6/13	29.9	23.5	96	79	210.8
4/6/13-10/6/13	29.4	22.8	95	79	149.2
11/6/13-17/6/13	28.6	22.3	97	87	302.5
18/6/13-24/6/13	27.5	23.0	98	86	284.1
25/6/13-1/7/13	28.6	22.9	96	83	172.2
2/7/13-8/7/13	28.6	22.8	97	85	247.5
9/7/13-15/7/13	28.4	22.8	97	85	172.7
16/7/13-22/7/13	27.5	22.7	97	90	276.8
23/7/13-29/7/13	28.5	22.3	96	79	207.8
30/7/13-5/8/13	28.9	22.8	96	81	185.8
6/8/13-12/8/13	29.0	23.5	96	72	89.9
13/8/13-19/8/13	29.9	23.1	96	71	37.2

Period	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (morning) %	Relative humidity (noon) %	Rainfall (mm)
20/8/13-26/8/13	30.0	22.5	97	69	20.5
27/8/13-2/9/13	31.9	23.2	94	68	0.4
3/9/13-9/9/13	29.8	22.0	96	75	66.2
10/9/13-16/9/13	29.4	22.1	96	79	158.4
17/9/13-23/9/13	29.1	22.7	96	76	104.3
24/9/13-30/9/13	31.0	21.6	93	69	10.4
1/10/13-7/10/13	30.9	21.9	96	62	17.8
8/10/13-14/10/13	30.7	22.6	96	69	60.1
15/10/13-21/10/13	30.8	23.1	96	72	150.6

Source: Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, Thrissur

APPENDIX II

Cost of cultivation of cabbage inside rain shelter (100 m^2) during off-season

Items	Cost (Rs.)
A. Labour charges	
1. Nursery preparation (1W)	225
2. Land preparation (2M)	660
3. Transplanting (1W)	225
4. Irrigation (1M)	330
5. Fertilizer application (basal dose) (1W)	225
6. Weeding and top dressing (2W)	450
7. Plant protection chemical application (1M)	330
8. Harvesting (1W)	225
B. Other inputs	
1. Cost of seed and potting media	100
2. Manures and fertilizers	400
3. Plant protection chemicals	100
C. Cost of structure	
1. Construction cost	2000
2. Maintenance cost	1000
Total cost	**6270**

STANDARDIZATION OF PLANTING TIME FOR OFF-SEASON CABBAGE (*Brassica oleracea* L. var. *capitata)* PRODUCTION IN RAIN SHELTER

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study entitled 'Standardization of planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata)* production in rain shelter' was undertaken in the Department of Olericulture, College of Horticulture, Vellanikkara during May-October 2013. The objective of the study was to standardize planting time for off-season cabbage (*Brassica oleracea* L. var. *capitata*) production in rain shelter.

The experiment was laid out in Randomized Block Design with four replications. The cabbage hybrid NS 43 of Namdhari Seeds Pvt. Ltd. was used for the study. The treatments comprised six planting dates namely May 15th, May 30th, June 15th, June 30th, July 15th and July 30th. The crop was raised inside two rain shelters each of 100 m^2 floor area. Observations on quantitative and qualitative characters of cabbage were recorded during the course of study.

Head formation was noticed in all dates of planting eventhough rainy season is an off-season for cabbage. There was no significant difference between planting dates with respect to plant spread, number of non wrapping leaves, stalk length, core length, head index and total number of marketable heads.

The lowest number of wrapping leaves was observed for May 30th (3.9) planting which was on par with May 15th (4.0) planting. May 30th planting took the minimum number of days to reach 50% head formation (47.50 days) which was on par with May 15th (48 days) planting. The minimum number of days to reach 50% head maturity was observed for May 30th (63.75 days) planting which was on par with May 15th (68 days) and July 30th (67 days) planting.

The highest net head weight was observed in May 15th (818.75 g) planting whereas the lowest was recorded in June 15th (486.25 g) planting. May 15th planting

recorded the maximum value for head characters like head length (13.55 cm) and head breadth (15.73 cm). The highest harvest index was also observed in May 15th (60.79) planting while the lowest harvest index was observed in June 15th (53.05). The yield/plot was highest for May 15th (11.78 kg) planting.

Moisture content was found minimum for June 15th (93.41 %) planting. The head shape of cabbage was round in all the planting dates. With regard to head compactness, all the heads were observed to be loose. The major pest observed during all the planting dates was tobacco caterpillar (*Spodoptera litura* F.). Incidence of soft rot (*Erwinia carotovora*) was noticed in all dates of planting. A physiological disorder called internal tip burn reported to be caused due to calcium deficiency was noticed in heads in all planting dates. The lowest pest and disease incidence was observed for May 15th planting. Considering the yield and lower pest and disease incidence, May 15th planting was found ideal for off-season cultivation of cabbage inside rain shelter.