PERFORMANCE ANALYSIS OF TROPICAL CABBAGE (*Brassica oleracea* Var *capitata* L.) HYBRIDS UNDER OPEN AND PROTECTED CONDITIONS

by

MALU. K

(2009-12-112)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF OLERICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2011

DECLARATION

I, **Malu. K (2009-12-112)**, hereby declare that this thesis entitled **"Performance analysis of tropical cabbage (*Brassica oleracea* var *capitata* L.) hybrids under open and protected conditions"** 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.

Malu. K

Vellanikkara
Date: 27/08/2011

Dr. P. Indira
Professor
Department of Olericulture
College of Horticulture
Kerala agricultural University
Vellanikkara, Thrissur, Kerala

Date:27/08/2011

CERTIFICATE

Certified that this thesis, entitled **"Performance analysis of tropical cabbage (*Brassica oleracea* var *capitata* L.) hybrids under open and protected conditions"** is a bonafide record of research work done independently by **Miss. Malu. K (2009-12-112)** 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
Chairperson
Advisory Committee

CERTIFICATE

We, the undersigned members of the advisory committee of **Miss Malu. K (2009-12-112)**, a candidate for the degree of **Master of Science in Horticulture**, agree that this thesis entitled **"Performance analysis of tropical cabbage (*Brassica oleracea* var *capitata* L.) hybrids under open and protected conditions"** may be submitted by her in partial fulfillment of the requirement for the degree.

Dr.P. Indira,
Professor,
Dept. of. Olericulture,
College of Horticulture,
Vellanikkara,Thrissur
(Major Advisor, Advisory Committee)

Dr .T. E. George ,
Professor and Head
Dept. of Olericulture
College of Horticulture
Vellanikkara, Thrissur
(Member)

Dr. T. Pradeepkumar,
Associate Professor,
Dept. of Olericulture
College of Horticulture
Vellanikkara, Thrissur
(Member)

Mr .S. Krishnan,
Associate Professor
Dept. of Agricultural Statistics,
College of Horticulture,
Vellanikkara ,Thrissur
(Member)

ACKNOWLEDGEMENT

I bow to the lotus feet of ***Almighty*** *whose grace had endowed me the inner strength, patience, will power and health to complete this endeavour successfully.*

At this moment of accomplishment, my heart is overwhelmed with gratitude and I wish if these words could convey the subtle feelings.

I am ineffable in expressing my deep sense of gratitude to ***Dr.P. Indira,*** *Professor, Department of Olericulture, College of Horticulture, Vellanikkara, Chairman of my advisory committee, for her inspiring guidance, constant supervision, support and encouragement throughout the course of my study period and in the preparation of the thesis.*

Words fail to express my indebtedness with veneration and devotion to ***Dr. T.E. George,*** *Professor and Head, Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee for the valuable guidance, close scrutiny, precious suggestions and help rendered throughout my study.*

I also owe my deep sense of gratitude and sincere thanks to ***Dr. T.Pradeepkumar,*** *Associate Professor, Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee for his support, suggestions and guidance throughout the study.*

I take this opportunity to express my heartful gratitude to ***Mr. S. Krishnan*** *,Associate Professor, Department of Agricultural Statistics, College of Horticulture, Vellanikkara and member of my advisory committee for his suggestions, valuable guidance and accommodating with all facilities for the successful completion of my research work.*

Words fall short as I place on record my indebtedness to ***Dr. K.P. Prasanna, Dr. K. Krishnakumari, Dr. Salikutty Joseph, Dr. Baby lissy Markose,Dr. Nirmala Devi, Dr. K.V. Suresh Babu, and Dr.P. G. Sadankumar*** *Department of Olericulture for their untiring support during my course of study.*

.

I also avail this opportunity to express my gratitude to ***Dr. Jim Thomas,Dr. Sosamma Jacob****, Department of Agricultural Entomology, and* ***Dr. Sally K. Mathew,*** *Professor and Head, Department of Plant Pathology for the enormous help they rendered at various occasions of my research work.*

I wish to express my sincere thanks to ***Sri. Unni*** *and* ***Smt. Jansi*** *for their kind cooperation and timely assistance during the field experiment studies.*

I also express my gratitude to all the non-teaching staff members and labourers of Department of Olericulture for their whole-hearted cooperation and timely assistance.

My heartfelt gratitude cannot be captured in words for the unflinching support, constant encouragement, warm concern, patience, valuable advice and helping hands of my friends ***Sreeja, Hajara, Chandana, Reeja, Divya, Amritha, Anu and Lini*** *and my classmates* ***Seeshma, Anisa, Ankita and Kannan*** *whose prayers, love and affection rendered me a successful path which propped up my career all along. I deeply express my special whole hearted thanks to my dear friends* ***Renjith*** *and* ***Greeshma*** *for their great understanding, constant support and encouragement. I wish to express my sincere gratitude to my seniors* ***Ms. Shijini, Ms. Kavya, Mrs. Jyothi, Mr. Koteswara Rao and Mr. Alex*** *for their wholehearted support. A special word of thanks goes to my roommates* ***Anju*** *and* ***Karthika****. I am in dearth of words to express my strong emotions and gratitude to my juniors, classmates and friends.*

The award of KAU merit scholarship is gratefully acknowledged.

Above all, I am forever beholden to ***my loving parents, my sisters, and my family members*** *for their constant prayers, affection, moral support, personal sacrifice and sincere encouragement throughout the period of my studies.*

Malu. K

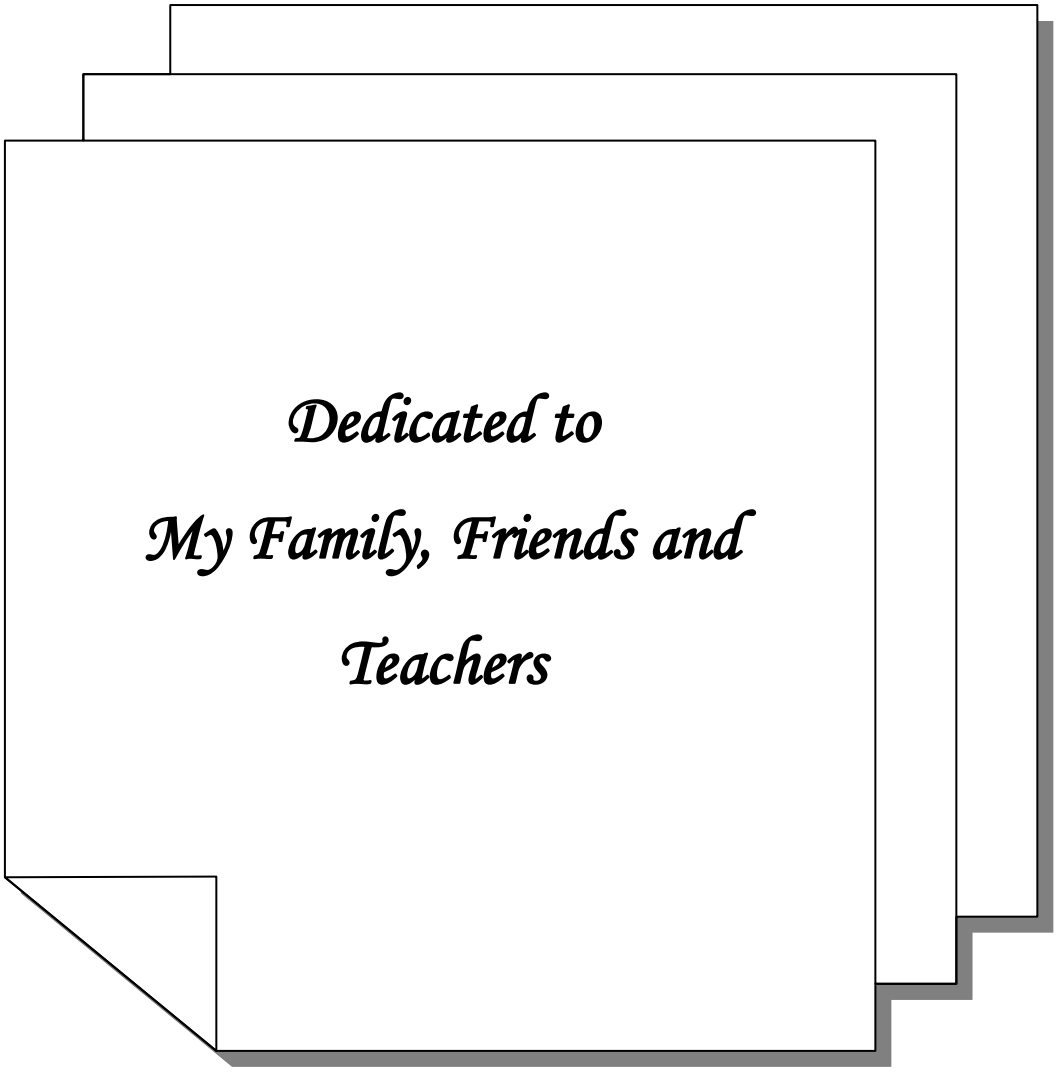

Dedicated to
My Family, Friends and
Teachers

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

The productivity and quality of a crop attain its maximum potential when grown in an environment that is optimum for that particular plant species. Suitable and meaningful manipulation of environment is very important for sustainable agricultural development. In controlled environment practices or greenhouse cultivation we can ensure optimum climatic condition in order to achieve maximum productivity.

Diverse climatic conditions prevailing in different parts of Kerala resulted in the cultivation of a variety of vegetable crops differing in temperature requirement, cultivation practices and parts used. Cool season vegetables are grown in Idukki, Wayanad districts and high altitude regions of Palakkad district where mild sub tropical climate conducive for the cultivation of these vegetables prevails. Potato, cabbage, cauliflower, carrot, onion, and garlic are the important cool season vegetables cultivated in these areas. With the development of tropical cabbage and cauliflower, their cultivation has spread to non traditional areas also. Popularisation of cool season vegetable cultivation in plains will help to minimize truckloads of cabbage and cauliflower coming from neighbouring states flooded with toxic pesticides and helps to increase overall vegetable production of the state.

Cole crops in general are sensitive to weather conditions. Cabbage is an important cole crop grown under temperate to tropical conditions for its head. It is cultivated in more than ninety countries throughout the world (Singh *et al.*, 2009). In India it ranks second next to cauliflower in area and production (Rana, 2008). The potential yield of cabbage (*Brassica oleracea* L. var. *capitata*) is determined by appropriate husbandry practices and the surrounding environment provided to the crop.

Earlier, the cultivation of cool season vegetables like cabbage was not possible in Kerala plains. Recently, due to the tropicalisation of cool season vegetables, their cultivation has become a profitable venture in Kerala plains also and with the help

of protected cultivation technologies they can be cultivated even during off- season when the prices are high.

Kerala being a high rainfall state with high humidity, water logging and biotic stresses are the major problems for the outdoor production of vegetables during rainy season. Among different kinds of protected structures, it was found that naturally ventilated polyhouse named as "rain shelter" is ideal for the humid conditions of Kerala.

Rain shelter is a naturally ventilated low cost polyhouse with only roof cladding and open sides. Its frame work can be made permanent with G.I pipes or temporary with termite proof arecanut or bamboo poles. Cladding is provided with UV stabilized polythene film of 200 micron thickness. There is much scope for the cultivation of cool season vegetables inside these rain shelters during off- seasons.

Hence, this study was attempted to identify an ideal hybrid of tropical cabbage for plains and also to study the feasibility of cabbage cultivation in protected and open field conditions during on and off- season.

Review of Literature

2. REVIEW OF LITERATURE

Cruciferous vegetables are one of the most important group of vegetables cultivated all over the world. They are rich source of dietary nutrients and antioxidants. Their cultivation is now possible in humid tropical areas through tropicalisation of varieties. This chapter provides a review of the relevant literature on the effect of growing conditions, weather parameters and climatic factors on cole crops. It also includes the effect of different factors on growth, yield and quality of cole crops. The effect of pest and diseases on cole crops and the economics of cultivation of cole crops are also reviewed. The available literature is reviewed under the following major heads.

2.1. Effect of growing conditions on cole crops

2.1.1. Type of structure and system

2.1.2. Season/ time of cultivation

2.1.3. Cultivar

2.2. Effect of different factors on plant growth, yield and quality of cole crops

2.2.1. Plant growth

2.2.2.. Yield

2.2.3. Quality

2.3. Effect of climate and weather conditions on cole crops

2.3.1. Temperature

2.3.2. Light

2.3.3. Humidity

2.4. Effect of pest and diseases on cole crop

2.5. Economics of cultivation

2.1. EFFECT OF GROWING CONDITIONS ON COLE CROPS

2.1.1. **Type of Structure and System**

Strong wind, high rainfall, spread of disease during rainy season and pest problems in open field agriculture have led to the current trend of growing lowland cauliflower under the protected environment which included rain shelter and greenhouse (Ilias and Ramli, 1994).

According to DuhSukh (1999) summer production of chinese cabbage in low lands of Korea was made possible through the successful prevention of soft rot and viral diseases by using rain shelters.

Suseela (2002) noted that, in 4.5m height naturally ventilated greenhouse, at 0% roof ventilation and 5% side ventilation, the average temperature rise (at 1m above the floor level) above the ambient temperature was 3.54^0C whereas in 3m height greenhouse, roof slope as well as height of the greenhouse accelerated the upward movement of hot air, which helped to attain a lower temperature in the crop zone. But in the case of 3m height greenhouse, lesser height and roof slope retarded the upward movement of hot air, which caused a higher temperature in crop zone. So 4.5m height naturally ventilated greenhouse is more suitable for growing cauliflower in tropical conditions like Coimbatore.

A study with cabbage was carried out in a polythene film greenhouse, involving two cultivars (Golden Acre and Santorin) and two systems of protection: a simple one with plastic tunnel protection and double one realized by the tunnel and a non-wooven crop cover that was placed immediately after planting. Plant growth was affected by the system of protection at the beginning of vegetation. Golden Acre and Santorin recorded a yield of 43.9 and 50.5 tonnes /ha; the yield increase was 15%. Double system of protection provided a yield increase of 33.5 tonnes /ha which was 13.5 tonnes/ha higher than the simple system of protection
(Apahidean *et al.*, 2004).

The mean commercial yield of chinese cabbage (*Brassica oleracea* var *pekinensis*) was 11.9 kg/m^2 under row covers but only 2.1 kg/m^2 in open air; owing primarily to

the important number of marketable cabbage in a study conducted in Spain. The foliar calcium content in the outer leaves was significantly greater in the open field, whereas the reverse was true in the case of inner leaves. This encouraged tip burn in open conditions. The use of row covers constituted a low cost technique to improve open air cultivation of chinese cabbage (Hernandez *et al*., 2004).

According to Sanwal *et al*. (2005) seedlings of vegetables like cabbage, cauliflower are grown under plastic covers protecting them against frost, severe cold and heavy rains. The environmental conditions, particularly increase in temperature inside polyhouse hastens the germination and early growth of warm season vegetable seedlings for raising early crops in spring summer.

LDPE (Low density polyethylene film) greenhouse and low tunnels have been extremely beneficial for cabbage, cauliflower, cucumber, lettuce, onion, spinach, brinjal, pepper, turnip, radish and tobacco crops (Kumar, 2006).

According to Mahajan (2006) the survival of the seedlings under polythene sheet was significantly higher than the control. Mean survival of seedlings over control in cauliflower was 76 % of seedlings raised under polythene sheet were erect, well developed, healthy and strong.75.5% increase in seedling weight was also noticed.

Raising of seedlings with nylon net covering on nursery beds or hi-tech mass production using plug trays or flats in greenhouse (net or polyhouse) gives good quality and healthy seedlings (Prabhakar and Hebbar, 2006).

A study was conducted on the development of an environment control system for selected temperate crop production in the lowland tropics. It involved the design and development of fully controlled environment greenhouse system to provide year round summer conditions suitable for temperate crops. Cole crops like broccoli, cauliflower, and other high value crops were selected for production trial. The design of the controlled system was based on the principles of internal air space strata specific conditions and temperature gradients which controlled day/night temperature, light, root temperature, day length, CO_2 level etc (Sharif, 2006).

Kamaruddin (2007) reported that high value temperate and tropical crops such as tomato, capsicum, cabbage, musk melon, cucumber were successfully grown under naturally ventilated structure using hydroponics system in the low lands. The yield of the crops was found 2-4 times higher when compared to open field conditions. Year round production of premium quality vegetables is also possible. In addition it reduced labour requirement and saved operational time.

According to Anuja *et al*.(2008) low cost bamboo based greenhouse structures covered with polythene are now within the reach of small and marginal farmers. Small and low cost greenhouse structures are of great value in raising nursery of offseason vegetables during severe winter months. Chinese cabbage, celery, amaranth, coriander, fenugreek, tomato, palak etc are the vegetables suitable for polyhouse cultivation.

Cauliflower production is constrained by biotic and abiotic factors such as heavy rains, high temperature and high incidence of pest and diseases and weed competition. As a result, it often undergoes yield losses and quality degradation in the open field especially in relatively hot areas. These problems were overcome by controlling the environmental conditions and meeting the nutrient requirement up to near optimum levels. This is only possible through protected environment combined with a suitable hydroponics system. (Ranawana *et al.*, 2008).

Considering the suitability of structure and economics, naturally ventilated gable roof greenhouse having 3.75m ridge height with 20% side ventilation and 6% roof ventilation oriented in North- South direction was recommended for Coimbatore district for cauliflower cultivation. Greenhouses were constructed using locally available casuarina poles and arecanut reapers and were covered with UV stabilized polyethylene sheets. To prevent the entry of insects and pests, insect-nets were provided at the roof and side ventilators. (Suseela, 2008b).

In an experiment conducted to study the climatic parameters and application of greenhouse technology of crop production in cold desert region of India (Spiti valley area), it was revealed that modifying environmental conditions in cold desert region adapting greenhouse technology enable to grow vegetable crops. Different shaped

greenhouse structures were constructed and flexibility of growing vegetable crops like coriander, lettuce, brinjal, mint, cabbage etc were tested. Trench type greenhouse provided better yield than other types of greenhouse structures (Bhagat *et al*., 2009).

2.1.2. Season/ Time of Cultivation:

In a study conducted by Saikia *et al.* (1998) the effect of transplanting date on the growth and yield of seven cultivars were evaluated under a UV stabilized LDPE (Low density polyethylene) rainshelter. The best yields were obtained from seedlings transplanted on August 29. Pusa Katki recorded the highest curd yield of 153.82 kg/100 m^2.

Earlier studies in cauliflower at Regional Agricultural Research Station, Ambalavayal showed normal formation of curds in cauliflower when planted during the month of October (KAU, 1999).

According to Pradeepkumar *et al*.(2002) out of the six cultivars of cauliflower viz. PES-1, F1-598, PES-3, Pusa Early Synthetic (all early types), Pusa Sharad (mid) and Super Snowball (late), the highest yield was obtained with the early planting (7.512t/ha) and among the varieties, PES-1 was superior in all the planting dates (5.801t/ha). Significant interaction was observed between varieties and planting time with respect to yield.

Kleinhenz and Wszelaki (2003) reported that cultivar- planting date interactions were significant for head density, ratio of head polar and equatorial diameter and core base width. The weight of individual market ready trimmed heads showed a strong quadratic relation to average head diameter.

According to Theodore *et al.* (2004) harvest time influenced the head traits. Head weight, diameter, volume, density and core volume generally increased with harvest date, while the ratio of head polar to equatorial diameter and the percentage of head volume occupied by the core decreased. Strong curvilinear relationships between head mean diameter and head weight was found.

An experiment was conducted at experimental farm of Highland Agricultural Research and Extension Centre of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Kukumseri during summers of 2001 and 2002 to find out the optimum time of transplanting for Cauliflower (*Brassica oleracea* L. var *botrytis* L.subvar *cauliflora* DC). Out of the treatment combinations of planting dates (18 May, 2 June, and 17 June) and cultivars (Pusa Snowball K1, Palam Uphar, Pusa Himjyoti) interaction effects indicated that transplanting of Pusa Snowball K1 on 2 June gave maximum marketable curd yield (24.7t/ha) combined with better performance of average curd weight, gross and net curd weight, curd diameter and curd size index. The maximum net returns (Rs.257000/ ha) and B:C ratio 6.4:1 were also obtained from the same combination. (Sharma *et al*., 2006).

In a study conducted in Tamilnadu Agricultural University, Coimbatore, the duration of cauliflower crop under greenhouse was less than three months (65-75 days) and hence four crops could be cultivated inside greenhouse. The crop duration in open field was more than three months. Hence maximum three crops could be cultivated in a year. (Suseela, 2008b).

According to Singhal *et al*. (2009) the per plant weight of broccoli was markedly influenced by the date of planting and spacing and their interactions.

2.1.3. Cultivar:

According to Lal (1993) the early maturing cultivars produced lower yields due to a shorter growing season, while the medium and late maturing cultivars gave higher yields because of exposure to cold climatic conditions for a longer period.

Nowbuth (1997) reported that different genotypes make the cultivation of cauliflower possible over a range of climatic conditions. Some varieties of cauliflower stay vegetative when grown under high temperature. According to Sharma and Verma (2000) among different cultivars evaluated Hybrid Bahar recorded significantly higher head weight (893g) over all other varieties. The minimum stalk length was recorded in Hybrid Bahar (0.77cm) which was statistically on par with Pusa Mukta(0.84cm). Golden Acre followed by Bahar and Pride of India were earlier to mature, forming markaetable heads in 78.8, 81.8 and 82.6 days respectively.

In a study conducted at Kerala Agricultural University, seven lines of cabbage were raised in RBD with three replications. Among the seven lines of cabbage tested viz. Questo, DTC513, Pusa Ageti, DT-507-4, Golden Acre, Japanese Hybrid, and Red Cabbage, significant difference was observed for all characters under study. DTC 513, Pusa Ageti, DTC-507-4 and Red Cabbage were the earliest to form head and statistically on par. Questo produced highest number of non wrapper leaves. (KAU, 2001).

Heat tolerant varieties had greater water uptake than heat sensitive ones at the onset of head formation. Heat tolerant varieties also possessed thicker leaves, higher leaf sap electrical conductivity and chlorophyll content and lower stomatal number. These characteristics appeared to facilitate water transport to the leaves and reduce transpiration, thus enabling the heat tolerant plants to maintain leaf turgidity during the heading stage at high temperature. Vigorous root growth also found essential to supply adequate water to the leaves so that they can maintain good turgor at high temperature (Kuo *et al*., 2002).

Out of the 23 genotypes checked, Golden Acre (78.25) was found to be earliest to mature and Pride of Fuji took maximum time (100.54) to reach maturity, very closely followed by Krishna (100.25) in a study conducted in G.B pant University of Agriculture and Technology. The maturity duration varied from genotype to genotype, which could be due to their inherent potential as well as environmental influence (Chaubey *et al*., 2006).

According to Yau *et al*. (2006) among the six cabbage cultivars viz. KK cross, Summer Autumn, King of kings, Beijing Siji, Orient Express, and Magic Ball evaluated under plastic rain shelter on mineral soils at Malaysia, Summer Autumn resulted in highest yield of 25.8 t/ ha. Magic Ball and Orient Express cultivars were relatively very tolerant to bacterial soft rot attacks.

A comparative evaluation of yield characteristics of different cabbage varieties were undertaken in different types of greenhouses and open field , under Kerala conditions.NS 43, NS 183, Gaurav preformed well and maximum yield was obtained

in greenhouses having a height of 4.15m oriented in North- South direction(Suseela, 2008a.)

Trials conducted at Agricultural Research Station, Mannuthy revealed that cabbage lines NS 43 and NS160 were high yielders and they performed well under Kerala conditions also (KAU, 2009). Pradeepkumar and George (2009) reported that F1 hybrids of cabbage like Quisto and Hari Rani Gol performed very well under Kerala plains during the period from October to March.

2.2. EFFECT OF DIFFERENT FACTORS ON GROWTH, YIELD AND QUALITY OF COLE CROPS

2.2.1. **Plant Growth**

In cabbage the higher number of non- wrapper leaves is considered as an undesirable trait. (Agarwal *et al.*,1972). Isenberg *et al.* (1975) recorded increases in weight and density of cabbage over a period beginning approximately 100 days after planting and found that the changes in weight and density were cultivar dependant.

Srihari and Satyanarayanan (1992) noted that leaf size in cabbage had direct bearing on plant spread. The performance of plant roots is influenced by the root zone temperature and oxygen content (Donnan, 1993).

According to Yungwei (1995) germination percentage, plant fresh weight and leaf area were greatest in the greenhouse followed by the plastic house. The survival rate and yield from transplants raised in the greenhouse and plastic house were better than those from net house.

In head cabbage (*Brassica oleracea* L. *capitata* group) the formation of true leaves is followed by a three stage developmental sequence culminating in horticultural maturity: frame development, cupping and head initiation and head development (Rubatzky and Yamaguchi, 1997).

According to Suseela (2002) there was no significant variation in plant spread, plant height and number of leaves among the various greenhouses which differ in their ridge heights. The plant spread and plant height in the open field was significantly

lower than all the greenhouses but not the number of leaves. The plant spread in the 3m greenhouse was significantly lower than that in 3.75m greenhouse. But the 3.75m and 4.5m greenhouses were on par. The number of leaves in 3m greenhouse was significantly lower than the 3.75m greenhouse.

A cabbage forms its head during the vegetative growth period. The number and size of head leaves increases until the head acquires a weight, size and tightness suitable for harvest (Tanaka and Niikura, 2003).

According to Takegawa *et al. (*2004), in cabbage relative growth rate of estimated leaf area (ELA) was larger and ELA enlargement was faster in 15-20 days old seedlings than 25 day old seedlings and they formed root balls. Thus 25 days seedlings that appeared to be ready for transplanting already got root retardation because of their root ball formation.

In broccoli, stalk diameter and number of leaves per plant are found to be increased with increased spacing (Singhal *et al.*, 2009). According to Singh *et al.* (2010) days to 50% maturity is having positive correlation with number of non- wrapper leaves and frame spread had positive correlation with gross plant weight, equatorial diameter, plant height, net head weight where as negative correlation with head compactness and head shape index.

2.2.2. Yield

According to Khatiwada (2001) the potential yield of cabbage (*Brassica oleracea* var *capitata*) is determined by appropriate husbandry practices and the surrounding environment provided to the crop.

Among the seven lines tested viz. Questo, DTC513, Pusa Ageti, DT-507-4, Golden Acre, Japanese Hybrid, and Red Cabbage, Japanese Hybrid and Pusa Ageti exhibited highest gross weight and net weight of head. Japanese Hybrid exhibited highest plot yield followed by Pusa Ageti (KAU, 2001).

In a study conducted by Mehta *et al.*(2003), the performance of cauliflower cultivar Aghani, knol khol cultivar Earliest White, and cabbage cultivar Pride of India, under greenhouse and open field conditions were analysed and it was revealed that the

yields of cauliflower(5.47kg/m^2), knol khol(3.61kg/m^2), and cabbage (8.55kg/m^2)were highest under greenhouse conditions.

According to Sharma and Behera (2003) for the early Indian cauliflower, the genotype X environment interactions were significant for yield per plot (2.7), maturity days (42.4), harvest index (10.7) and riceyness (28.0). Indian cauliflower was greatly influenced by the environment through its characters namely yield, maturity, harvest index, curd colour and curd compactness for marketable yield.

Studies revealed that among the seven cabbage varieties tested variety September is the highest yielder (30.28t/ha followed by Sri Ganesh, Hari Rani, IAHS2, and Hybrid 43 (Gopalakrishnan, 2004). Suseela (2008b) reported that both quality of curd and yield up to 5.4 tonnes could be increased considerably by cultivating cauliflower inside greenhouses.

The association of characters and magnitude of their relationship with other characters at phenotypic level revealed that net head weight had significant positive correlation with gross plant weight, equatorial diameter, polar diameter, frame spread, plant height, core length and harvest index (Singh *et al*., 2010).

In a study conducted at Horticultural Research Station of HNB Garhwal University, Srinagar; it was observed that among the varieties tested Pride of India (1.45 kg) followed by Golden Acre (1.18 kg) were having high net head weight and minimum was found in Pusa Mukta. Maximum head diameter was also found in Pride of India (18.68cm) followed by Golden Acre and minimum in Pusa Mukta (16.6cm) (Rana and Singh, 2010).

2.2.3. Quality

The content of Vitamin C in cauliflower is fairly stable, both in fresh and frozen produce. It varies with cultivars, maturity, environmental influence especially climatic and post harvest factors like storage conditions and storage period (Pearson, 1979).

Cabbage is a good source for carbohydrates, vitamins, minerals, amino acids and other biologically active substances (Huxsoll *et al*., 1989). Broccoli also is an important cole vegetable. It is a new crop in India which is nutritious among cole

crops being rich in vitamins and minerals and also a rich source of sulphoraphane, a compound associated with reduced risk of cancer (Kalia, 1995).

According to Amr and Hadidi (2001) the greenhouse grown vegetables were higher in their nitrate and nitrite content than those grown in open field. Cultivar had no significant effect on open field and greenhouse on nitrate and nitrite content. The harvest date was significant in open condition and not significant in greenhouse.

Greenhouse technology offers many resources to control the conditions of light, temperature, humidity, CO_2 content, water and nutrient availability. Thus indoor production of vegetables presents some advantages compared to outdoor production with regard to quality assurance (Bot, 2003).

Some of the glucosinolates found in Brassica vegetables are the principal source of anticarcinogenic activity in these vegetables. Especially the glucosinolates glucoraphanin, glucoiberin, glucobrassicin, and gluconasturtuin are involved in anti carcinogenic activity. Most species contain limited number of glucosinolates and there are quantitative differences between plant parts such as roots, leaves, stems and seeds. Even though the glucosinolates content is influenced by the environmental conditions, the effect of genotype is found to be greater than that of environmental factors (Farnham *et al*., 2004).

According to Khan *et al*.(2006) among the kale varieties tested in greenhouse maximum vitamin C was recorded in SH-K-21(171.70 mg/100g) followed by SH-K-1, SH-K-2,SH-K-10 and SH-K-33 with a vitamin content of 153.63,149.80, 148.23, 146.33, and 142.27 mg/100g fresh leaf sample.

Greenhouse grown broccoli cv Marathon was cultivated after head induction at three different daily mean temperatures in the range from 7.2 to 19.7^{o}C under two different daily mean radiation levels in the range from 1.9 to 13.4 mol m^{-2} day^{-1}.Contents of ascorbic acid, lutein and alkyl glucosinolates increased at daily mean temperatures between 7-13^{o}C combined with a moderate daily mean radiation of 10-13 mol $m^{-2}day^{-1}$ (Schonhof *et al*., 2007).

Cabbage is a rich source of sulphur containing amino acids, minerals, ascorbic acids and anti oxidants and is reported to have anti carcinogenic property (Singh *et al*., 2009 and Kopsell *et al*., 2004).

Red cabbage cultivars were found to contain significantly higher concentrations of glucoraphanin compared to the white cabbage cultivars. There were also significant differences within red cabbage cultivars (Hanson *et al*., 2010).

A study was conducted by Singh *et al*. (2010) to determine the variability of superoxide dismutase, peroxidise, and catalase activity in cabbage. The genotypes namely 83-2, Red Cabbage, KIRC-1-1, ARU Glory, KIRC-8 showed higher activity of antioxidant enzymes. Enzymatic antioxidant activity showed 1.6, 12.8, and 18.2 fold difference for superoxide dismutase, peroxidise and catalase activity respectively.

2.3. EFFECT OF CLIMATIC AND WEATHER CONDITIONS ON COLE CROPS

2.3.1.Temperature

Cabbage is known to be a green vernalization plant in which reproductive growth is induced by low temperature after attaining growth to a certain stage (Shinohara, 1959). Salter (1969) showed a close linear relationship between logarithm of curd size in cauliflower and thermal time indicating that the time to curd maturity was determined by the accumulated temperature.

Friend and Helson (1976) suggested that high growth rate obtained under a high day temperature was the result of high rate of photosynthesis. Kachru (1985) and Prasad (1997) had specified that the rate of progress towards flowering (curd initiation) increased with increasing temperature to an optimum temperature at which flowering was most rapid. At a temperature higher than the optimum temperature the flowering was progressively delayed.

Wien and Wurr (1997) reported that the formation of heads in broccoli and curds in cauliflower is primarily affected by temperature. In cauliflower as the temperature increased, the relative rate of vernalisation increased to a maximum and then declined.

Broccoli has a similar temperature response to cauliflower, although the upper temperature limit for head formation may be higher. Low temperatures are required to reduce competition for assimilates between developing leaves and apical meristem by suppressing leaf growth.

According to Nowbuth and Pearson (1998) the production of leaves in cauliflower was affected by both temperature and shade. Warmer temperature caused a decrease in number of leaves initiated. The number of leaves produced increased with temperature from 2-20^{0}C and further increase in temperature from 25-30^{0}C reduced the final leaf number.

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. Mean temperature above 23^{0}C hindered growth and provided pathogenic organisms with favourable environment to attack the chinese cabbage plants.

Cabbage is grown as summer crop in hills and as winter crop in the plains of North India. The optimum temperature for seed germination is 12-16^{0}C and for growth and heading between 15-20^{0}C, since the growth is arrested above 25^{0}C for temperate varieties. Young plants can withstand higher temperature and short spells of frost. Many tropical hybrids bred in Japan form tight heads even above 25^{0}C, thus staggering the availability over longer periods (Kanwar, 2001).

Ranghaswami *et al.* (2005) made an attempt to design and develop a naturally ventilated greenhouse suitable for tropical climate of Coimbatore district. The study evaluated the effect of height of greenhouse (3, 3.75, and 4.5m) and various levels of roof (0, 3 and 6%) and side (5, 10, 20, 25, 30, and 35%) ventilation on microclimate. The effect of microclimate on growth and yield parameters of cauliflower was studied. Under cropped condition temperature inside greenhouse decreases and relative humidity increases with increase in height of greenhouse. Cauliflower yielded better when average maximum temperature during vegetative and curd initiation stages inside the greenhouse was less than 30.5^0 C and when it exceeded 32.5^{0}C, showed abnormal vegetative growth and low yield.

Gericke (2007) reported that hot weather 85-100^{0}F prevents heading, too much water causes the head to burst and too humid conditions around the base of the plant stimulate leaf rot. Correlation coefficients between mean monthly rainfall during May and seed yield, mean maximum temperature during April and seed yield and maximum temperature during May and seed yield in Golden Acre variety cultivated in upper Kullu valley indicate that when temperature rise, it affects the seed production of cabbage adversely. Also, if rainfall increases during May, the seed yield is reduced. (Kumar *et al*., 2009)

2.3.2. Light

The *Brassica* genus as a whole appear to have either a long day or day neutral response to photoperiod and amongst these cabbage, brussels sprout, and kohlrabi have a day neutral response(Friend, 1985).

Light conditions during vernalisation were not important as long as optimum temperatures were used. However, if the night temperature was raised from 12^{0}C to 22^{0}C at decreased light intensity of 2.5 klux, curd formation was delayed and leaf number was increased (Wein and Wurr, 1997).

In a study conducted by Mourao and Hadley (1998) broccoli was grown on two occasions i.e. outside and under plastic film crop covers and under three light regimes using neutral screens to decrease solar radiation by 25-38%. It was found that dry matter accumulation was positively related to radiation level for both growing conditions. Under shaded conditions LAR and SLA increased and spear growth rate was positively related to incident solar radiation.

Nishijima and Fukuda (2006) examined the role of light in head formation of chinese cabbage in terms of hyponastic midrib bending i.e. autonomously induced during leaf growth. Before head formation, darkness induced hyponastic bending of midrib in the uppermost mature leaves. During early head formation, it occurred autonomously irrespective of irradiation.

Gericke (2007) reported that the thickness of cabbage leaves gave it the ability to resist injury from intense sunlight, yet it can also be grown in regions of limited

sunlight. It is well adapted to regions with short summer. It can withstand rather heavy frosts and thus can be both an early spring and a late crop.

2.3.3. Humidity:

Humidity is one of the most important environmental factor that influence the greenhouse vegetable plants and it consequently affects all processes that are associated with transpiration such as water balance, transpirational cooling and ion translocation (Bakker, 1984).

Major long term effect of humidity in greenhouse crops is through its effect on leaf area. Leaf expansion is favoured by humidity. The effect of humidity on relative growth rate was attributed to the small increase in net assimilation rate (Bakker, 1991).

2.4. EFFECT OF PEST AND DISEASES:

2.4.1.Diseases:

Clubroot disease of crucifers can occur at more than 46 percent of maximum water holding capacity. The disease severity increased with increase in soil moisture, and the severest attack occurs under water logged conditions (Horiuchi and Hori, 1980).

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 extent of 10-70% due to this disease have been reported in different *Brassica spp*. from different countries (Kolte, 1985).

According to Odour *et al*. (1996) downy mildew caused by *Perenospora parasitica* and black rot caused by *Xanthomonas campestris pv*. *Campestris* and ring spot were the most common diseases among *Brassicas*. Batal *et al*. (1997) reported that higher dose of Magnesium and Boron reduced the incidence of hollow stem in cauliflower.

According to Sharma *et al*. (2006), in cauliflower maximum disease index (50-60%) of downy mildew was observed during December-February when the temperature ranged between 15-22^{0}C. The *Sclerotiana* stalk rot index was maximum (30%) during February-March at a temperature 18-22^{0}C, whereas the *Alternaria* leafspot index was highest (>30%) in November-February at temperature ranged between 20 and 28^{0}C.

2.4.2. Pests:

Irradiation, temperature and humidity levels within greenhouse have a significant impact on the biology and dispersal of insect and mite pests and their biological control agents and the predatory parasitic interactions between them (Scopes, 1973).

The cultivation of cauliflower is hindered by the incidence of several pests viz., 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).

According to Odour *et al*. (1996) diamondback moth (*Plutella xylostella* L.), and cabbage aphid (*Brevicoryne brassicae*) are the major pest of *Brassicas*. In a study conducted at the National Agricultural Research Centre, Kenya diamondback moth was found to infest cabbage plants two weeks after transplanting and its population was inversely related to amount of rainfall. Other insect pests observed included leaf miners (*Liriomyza brassica*), thrips, cut worms, and loopers.

The seasonal incidence of several insect pests (aphids,cabbage butterfly (*Pierris brassicae*), cabbage leaf webber and diamondback moth infesting cabbage cv. Sabitri was investigated in a field in West Bengal, in two seasons, winter and spring. Results indicate that increase in temperature, sunshine hours per day, rainfall and decrease in relative humidity favour the multiplication of pests on spring cabbage. Spring cabbage was infested by a greater population of pests compared to winter cabbage (Choudauri *et al*., 2001).

Several trap crops like Indian mustard (*Brassica juncea* L.), collards (*B.oleracea* var *acephala*), and yellow rocket (*Barberea vulgaris*) a weed plant have been found to be effective attracting *Plutella xylostella* adults more over cabbage. Diamondback moth, a specialist folivore on cruciferous vegetable crops seem to be attracted to the

phytochemicals, like glucosinolates and their volatile hydrolytic products for its selective feeding and oviposition (Renewick, 2002).

Golizadeh *et al*. (2004) reported that population growth parameters of *P.xylostella* were significantly affected by temperature. On cabbage and cauliflower, the intrinsic rate of increase increased significantly as temperature increased from 10^0C to 28^0C. Population growth parameters of *P.xylostella* were investigated at broad temperature ranging from10^0 C to 35^0C. The life cycle of *P.xylostella* varied considerably depending up on various factors such as host plants and environmental conditions, under which it develops. The effect of temperature on development time may show a similar pattern for reproductive and survival parameters.

The diamondback moth, (*Plutella xylostella* (Linn)), Lepidoptera, Plutellidae) is the most destructive pest of crucifers throughout the world and is reported to cause more than 90 percent crop loss. (Sarfraz *et al*., 2005)

Correlation studies between larval population of diamondback moth, *Spodoptera litura* and mustard aphid and the major weather parameters indicated positive but non significant association between pest load and the maximum temperature while the association between larval population and minimum temperature was negative and significant. The relationship between larval population and morning relative humidity was positive and significant and the relationship with evening relative humidity was negative and non significant (Varalakshmi *et al*., 2006).

The bioefficacy of a new molecule, spinosad along with recommended insecticides and Bt formulation was evaluated against diamondback moth (*Plutella xylostella* L.) infesting cabbage under field condition during 2001 and 2002. Two sprays of each treatment were applied at attainment of ETL (2-3 DBM larvae/plant). At three days after first treatment lowest larval population (1.6/plant) was recorded in spinosad @20g ai/ha treated plot being at par with other spinosad and Bt treatments (Satpathy *et al*., 2007).

In a study conducted by Bhat (2008) in four cole crops namely cauliflower, cabbage, knol khol and kale in Kashmir, the presence of cabbage aphid (*Brevicoryne brassica*(Linn.)), cabbage looper (*Thysanoplusia orichalcea*), three species of cabbage butterfly viz. (*Pieris brassicae* (Linn.), *P. candida* (Sparrm.), *Pontia*

glauconome (Klug.), diamondback moth (*Plutella xylostella* (Linn.)), leaf miner (*Chromatomya horticola*) were revealed.

According to Patait *et al.* (2008) 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 0.6to 3.2 and 1.0 to 5.0, 1.0 to 1.6, 1.6 to 20.4 and 0.2 to 1.0 larvae per quadrat during rainy season and 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. During winter season, the population of *C.binotalis* and *P.xylostella* was affected positively due to the action of afternoon relative humidity and maximum temperature. The population of *S.litura* was influenced positively by forenoon relative humidity and negatively by minimum temperature and afternoon relative humidity.

Satpathy *et al.* (2010) suggested the probability of using chinese cabbage as a better trap crop over mustard as it constantly harboured more eggs of *P.xylostella*, besides the latter needs two sowings to prolong the attractiveness of the plants to the target pest which is not required in the case of chinese cabbage.

According to Voorips *et al.* (2010) the difference in thrips damage between varieties is mostly due to difference in resistance rather than tolerance. Early head development and increased brix levels were associated with increased thrips damage. Increased amount of leaf surface wax was associated with increased thrips damage. A combination of these traits can account for about 75 % of the variation for thrips damage between varieties.

2.5. ECONOMICS OF CULTIVATION

The operational and commercial costs were Rs. 2215 and Rs. 7094 /ha for the cultivation of cabbage in high hills of Uttar Pradesh. Labour cost accounted for nearly 74 percent of the total cost, where as material costs was about 16 percent in cabbage production. The return from cabbage cultivation can be increased through increased use of fertilizers, manures, bullock labour (Tripathi, 1999).

Another experiment to study the effect of inter crop on yield and monetary returns of cabbage in rabi season revealed that the combined yield of cabbage + palak was found

to be significantly higher than the remaining crop combination. The land equivalent ratio was highest in cabbage + methi than the remaining combinations. (Gowade *etal.*, 2004.)

In a study conducted by Mahajan (2006), two methods for raising cauliflower nursery were compared. In improved method, transparent polythene sheet with an inverted 'V' shape was used to cover the raised nursery bed keeping about 1.5 feet height at the edges from the raised bed surface and 3m at the centre. Cost of raising nursery in improved method was Rs.2340.00 for raising open pollinated variety and Rs.5740.00 for F1 hybrid with saving of Rs. 1343.00 and Rs.12420.00 over the control. There was about 68 percent saving of cost in case of hybrid nursery raised in improved method, than the control, which was mainly due to higher cost of hybrid seeds. The seedlings were earlier than the control, which saved time and labour.

The attack of pests and diseases in cauliflower was more in open field and also frequent weeding was done. Due to poor establishment of crop, more gap filling was done in open field. Hence cost of weeding and plant protection measures were more in this case. The B:C ratio for 3m greenhouse is found to be 1.528, 3.75m is 2.286 and 4.7m is 2.293 and in open field it is 1.168 (Suseela, 2008b).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-2011with the objective to study the performance of F1 hybrids of cabbage (*Brassica oleracea* var *capitata* L.) under protected and open conditions.

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:

A low cost rain shelter constructed in the Department of Olericulture was used for study (Plate 1.) and the design used was RBD. The frame of the rain shelter is made up of G.I pipes. Cladding is provided with UV stabilised low density polyethylene film (UVLDPE) having thickness of 200 micron. The floor area was $100m^2$ (20m x 5m) with a side height of 2m and central height of 3.5m.

3.2. OPEN FIELD:

Plain land adjacent to rain shelter was utilised for evaluation of open field crop.

3.3. VARIETIES:

Four F1 hybrids of cabbage were used for the study (Plate 2). They were evaluated during both the seasons in rain shelter and open field simultaneously in a randomised block design with four replications. Details of F1 hybrids used are given in Table3.1.

Plate 1. Rain shelter

Table3.1. Name and source of hybrids used for the study

Sl no.	Name of hybrid	Source
1.	NS 183	Namdhari seeds Pvt. Ltd
2.	NS 43	Namdhari seeds Pvt. Ltd
3.	NS 35	Namdhari seeds Pvt. Ltd
4.	Disha	Seminis India Ltd.

3.4. SEASONS:

The research was carried out in two seasons viz. July - Oct 2010 (Off- season) and Oct 2010 - Jan 2011(on- season) under two conditions (rain shelter and open field).

3.5. CULTURAL OPERATIONS:

3.5.1. Nursery practices:

Seeds were sown in plug trays filled with rooting medium of vermicompost and sand in the ratio of 1:1 and one month old seedlings (Plate 3.) were transplanted to the prepared main field

NS 183

NS 43

NS 35

Disha

Plate 2. F1 Hybrids

3.5.2. Preparation of main field:

The experimental field was (open field and rain shelter) cleared and ridges were taken in each plot ($3m^2$) and a basal dose of farm yard manure at the rate of 25t/ha was applied before transplanting. Seedlings were transplanted at a spacing of 45 X 45 cm (KAU, 2007). Field was laid out in randomised block design with four replications. There were ten plants per replication. Gap filling was done ten days after transplanting.

3.5.4. Fertilizer application:

Urea, superphosphate, and potash were the source materials for supplying nutrients N, P_2O_5 and K_2O respectively. These nutrients were mixed based on the package of practices recommendation 150:100:125 kg/ha. Full dose P_2O_5 and half dose of N and K_2O were applied before transplanting and remaining half dose was applied one month after transplanting (KAU, 2007).

3.5.5. After cultivation:

Regular weeding and earthing up were done inside the rain shelter and in open field. Diseased and damaged plants were removed regularly.

3.5.6. Plant protection:

Seedlings were drenched with *Pseudomonas fluorescence* (20g/ L) to prevent nursery diseases. *Alternaria* leaf spot was controlled by spraying Mancozeb 2g/l in the main field. Ekalux 2ml/l was sprayed in nursery to prevent caterpillar attack. Fipronil 2g/l was sprayed in main field to control *Spodoptera litura*.

3.5.8. Harvesting:

Heads were harvested at marketable stage and observations were recorded.

Plate 3. Plug tray seedlings used for transplanting

3.6. OBSERVATIONS:

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

3.6.1. Early plant vigour:

Recorded 30 days after sowing and classified as follows:

1. Poor
2. Medium
3. Good
4. Others

3.6.2. Leaf colour:

Leaf colour was recorded at marketable stage and scores were given as

1. Green
2. Blue green
3. Dark green
4. Red
5. Purple
6. Others

3.6.3. Number of non wrapping leaves:

Non wrapping leaves or the leaves not covering the head portion were counted at marketable stage and mean value was taken.

3.6.4. Plant spread:

This was recorded as average of the distance between two outer leaves of five plants (in cm).

3.6.5. Number of wrapping leaves:

Wrapping leaves that cover the head were counted at marketable stage and average value was recorded.

3.6.6. Days to 50% head formation:

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

3.6.7. Days to 50% head maturity:

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

3.6.8. Total number of marketable heads:

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

3.6.9. 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

3.6.10. Head shape:

Shape of the heads were recorded at marketable stage as different head shapes like

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

3.6.11. Head length (cm):

Head length was recorded at marketable stage and mean was found out.

3.6.12. Head breadth (cm):

Breadth of selected heads was recorded and average was taken.

3.6.13. Head index:

Index was calculated as average ratio of head length to width.

3.6.14. Core length (cm):

Length of core region of heads was recorded and mean value was found out.

3.6.15. Stalk length (cm):

Stalk length was recorded at marketable stage as length of plants from ground level to the first non wrapping leaves.

3.6.16. Gross head weight (g):

Weight of heads was taken along with the non wrapping leaves and stalk at marketable stage.

3.6.17. Net head weight (g):

It was recorded at marketable stage as the weight of individual heads.

3.6.18. Harvest index:

It was calculated as the ratio of net head weight and gross head weight (economic yield and biological yield).

3.6.19. Pest and disease incidence:

Percentage incidence of pests and diseases was recorded both under protected and open conditions during off and on- season.

3.6.20. Meteorological observations:

Temperature and humidity were recorded daily under both conditions during the cropping period. Rainfall data during cropping seasons were collected from Principal Class 1 Agromet observatory, College of Horticulture, Vellanikkara.

3.6.21. Economics of cabbage production under rain shelter and open field:

Economics of cabbage production was worked out for the rain shelter crop and open field for both seasons. Total return was estimated with realized yield. Benefit: Cost ratio of each crop under both growing conditions were found for comparison.

3.7. STATISTICAL ANALYSIS:

The data recorded on vegetative and yield characters were statistically analysed by using statistical package (MSTAT-C) (Freed, 1986). Simple correlation between the plant characters like days to 50% head formation, 50% head maturity and yield per harvest with weather parameters like maximum and minimum temperature, relative humidity and rainfall were computed.

Results

4. RESULTS

The observations recorded on various growth and yield characters and weather parameters during the experimental period were analysed statistically and the results are presented below and general view of the fields during both seasons is given in plate 4 and 5.

4.1. Qualitative characters

4.2. Quantitative characters

4.3. Pest and disease incidence

4.4. Crop weather relationship

4.5. Benefit-Cost ratio

4.1. QUALITATIVE CHARACTERS:

4.1.1. Early plant vigour:

All the hybrids namely NS 183, NS 43, NS 35 and Disha exhibited good early plant vigour during both seasons. (Table 4.1 and 4.2)

4.1.2. Leaf colour:

The off- season crop showed colour variation in leaves under both protected and open conditions. Under protected condition leaves were blue green in colour irrespective of the hybrids while in open field the leaf colour was green (Plate 6.)

During on- season, all the hybrids showed blue green leaf colour irrespective of growing conditions. (Table 4.1 and 4.2)

Open field crop Rain shelter crop

Plate 4. General view of the fields during off season

Open field crop Rain shelter crop

Plate 5. General view of the fields during on- season

Green coloured leaves (open field)

Blue green coloured leaves (rain shelter)

Plate 6. Difference in leaf colour of cabbage grown in off- season

Table 4.1. Qualitative characters during off- season

Characters	**Treatments**							
	T1(NS 183)		T2(NS 43)		T3(NS 35)		T4(Disha)	
	Poly house	Open field	Poly house	Open field	Poly house	Open field	Poly house	Open field
Early plant vigour	Good	Good	Good	Good	Good	Good	Good	Good
Leaf colour	Blue green	Green	Blue green	Green	Blue green	-	Blue green	Green
*Head compactness	Medium compact-Compact	-	Compact	-	Medium compact-compact	-	Compact	-
*Head shape	Conical	-	Drum head	-	Conical	-	Conical	-

*Head formation was absent in open field condition during off- season

4.1.3. Head compactness:

During off- season, NS 183 formed medium compact to compact heads under protected condition while NS 43 formed compact heads. For the hybrid NS 35, the heads formed inside rain shelter were medium compact to compact and Disha formed compact heads in rain shelter. In open field, no heads were formed in NS 35 while one or two miniature heads were formed in other hybrids.

In main crop season, the hybrids NS 183 and NS 43 formed very compact heads under both growing conditions. Hybrid NS 35 formed compact heads under protected condition and very compact heads in open field while Disha formed very compact heads under rain shelter and compact heads in open condition. (Table 4.1 &4.2)

4.1.4. Head shape:

Head shape of all the hybrids except NS 43 was found to be conical during off- season inside rain shelter. NS 43 formed drum head shaped heads. During off- season head formation was not observed in NS 35 in open field and in other hybrids only one or two miniature heads were formed (Plate 7).

During on- season, NS 183, NS 35 and Disha formed round shaped heads under both growing conditions while NS 43 formed drum head shaped heads (Plate 8). (Table 4.1 &4.2)

Table 4.2. Qualitative characters during on- season

Characters	**Treatments**							
	T1(NS 183)		T2(NS 43)		T3(NS 35)		T4(Disha)	
	Poly house	Open field	Poly house	Open field	Poly house	Open field	Poly house	Open field
Early plant vigour	Good	Good	Good	Good	Good	Good	Good	Good
Leaf colour	Blue green	Blue green	Blue green	Blue green	Blue green	Blue green	Blue green	Blue green
Head compactness	Very compact	Very compact	Very compact	Very compact	Compact	Very compact	Compact	Very compact
Head shape	Round	Round	Drum head	Drum head	Round	Round	Round	Round

Drum head Conical

Plate 7 .Head shapes of hybrids during off- season

Drum head

Round

Plate 8. Head shapes of hybrids during on- season

4.2. QUANTITATIVE CHARACTERS:

4.2.1. Number of non wrapping leaves:

During off- season, lowest number of non wrapping leaves was observed inside the rain shelter. Hybrid NS 43 had the minimum number of leaves with a mean value of 7.40 which was on par with NS 35 (7.50) followed by the hybrid Disha (10.60) and NS 183 (11.70). Mean number of non wrapping leaves inside the rain shelter during off- season was 9.30. In the open field, lowest number of non wrapping leaves was observed in the hybrid NS 43 (9.42). NS 35 was (10.25) followed by NS 183 (13.00) and Disha (14.73). Mean value in the open field was found to be 11.85. (Table 4.3 and fig. 4.1)

During on- season also, the number of non wrapping leaves was found to be minimum in the hybrid NS 43 both inside the rain shelter and in open field. Inside the rain shelter the hybrid was having a mean value of 9.0 which was on par with NS 183 (9.08) and NS 35 (10.08). In open field, NS 43 was on par with NS 35 (9.50) followed by Disha (14.66) and NS 183 (16.08). Mean number of leaves inside the rain shelter during on season was 10.16 and in open field it was 12.39.(Table 4.4 and Fig.4.2)

4.2.2. Number of wrapping leaves:

Inside the rain shelter the hybrids NS 183 and NS 35 had maximum number of wrapping leaves (4.75) and they were on par with other treatments. Mean number of wrapping leaves inside the rain shelter was 4.45 (Table 4.3 and Fig. 4.1).

In the on- season crop, there was no significant difference between the number of wrapping leaves with respect to treatments and growing conditions. Inside the rain shelter maximum number of leaves was observed in the hybrid Disha (5.00) followed by NS 35 (4.66), NS 183 (4.33) and NS 43 (4.25). Under open field conditions, maximum number of wrapping leaves was observed in the hybrid NS 35 (5.25) followed by NS 183 (4.92), Disha (4.50) and NS 43 (4.16). Mean number of leaves inside the rain shelter was 4.56 and that in open field were 4.70. (Table 4.4)

Table 4.3 Number of non wrapping leaves and wrapping leaves during off- season

Treatments	**Non Wrapping leaves**		**Wrapping leaves**
	Polyhouse	Open field	Polyhouse
T1(NS 183)	11.70	13.00	4.75
T2(NS 43)	7.40	9.42	4.00
T3(NS 35)	7.50	10.25	4.30
T4(Disha)	10.60	14.73	4.75
Mean	9.30	11.85	4.45
CD(p<0.05)	**1.825**		**0.968**

Table 4.4. Number of non wrapping and wrapping leaves during on- season

Treatments	**Non wrapping leaves**		**Wrapping leaves**	
	Polyhouse	Open field	Polyhouse	Open field
T1(NS 183)	9.08	16.08	4.33	4.92
T2(NS 43)	9.00	9.33	4.25	4.16
T3(NS 35)	10.08	9.50	4.66	5.25
T4(Disha)	12.50	14.66	5.00	4.50
Mean	10.16	12.39	4.56	4.70
CD(p<0.05)	**3.20**		**NS**	

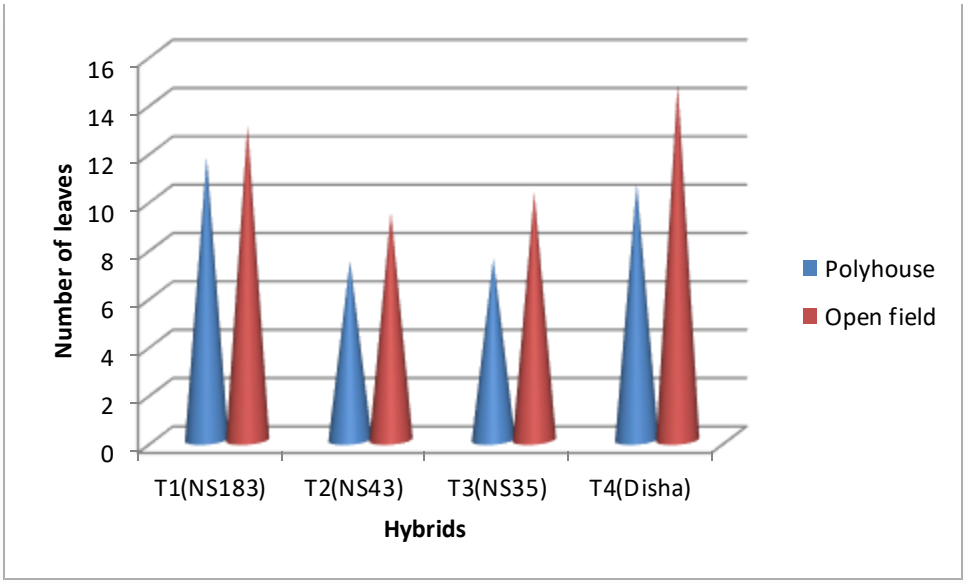


Fig 1.Comparison of number of non wrapping leaves during off- season

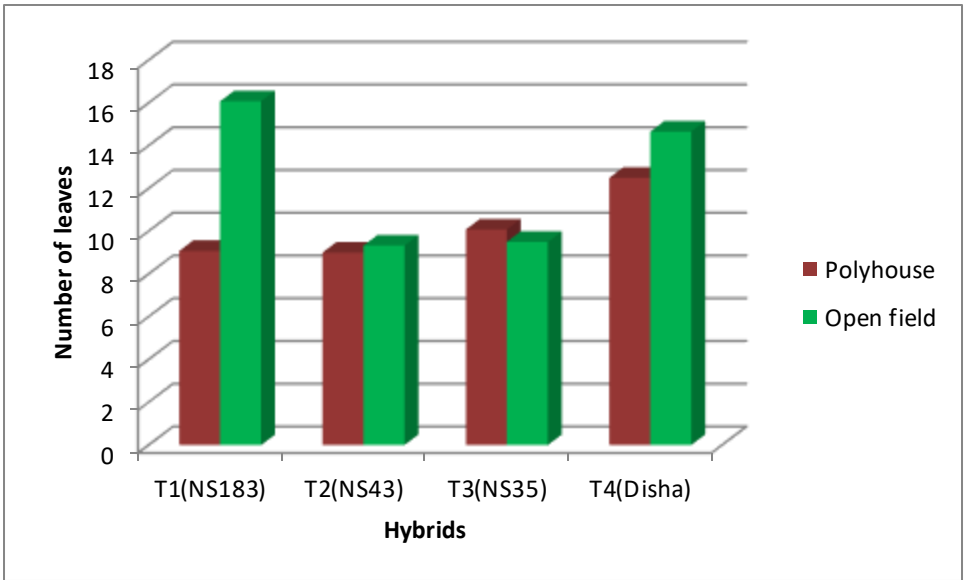


Fig 2. Number of non wrapping leaves during on- season

4.2.3. Plant spread:

During off- season, plant spread was found to be more inside the rain shelter than in the open field. Maximum plant spread was observed inside the rain shelter for the hybrid NS 43 (48.20cm) which was on par with the other varieties. The hybrids NS 183 and Disha were having a plant spread of 43.30 cm and 41.15 cm respectively inside the rain shelter and in open field during the same season their plant spread were 22.16cm and 22.17 cm respectively which were the highest. Hybrid NS 43 was having a plant spread of 21.67cm and NS 35 had 17.83cm. (Table 4.5 and Fig.4.3) (Plate 9)

It was observed that during on- season, inside the rain shelter plant spread was more in NS 35 (65.41cm) which was on par with NS 43 (61.91cm). The hybrid NS 183 was having a plant spread of 58.16cm and Disha had 57.08cm. NS 35 recorded maximum plant spread in open field (67.66cm) followed by NS 43 (59.25cm). Mean plant spread inside the rain shelter was found to be slightly higher than that in the open field. (Table 4.6) (Fig.4.4 and 4.5)

4.2.4. Stalk length:

During off- season, inside the rain shelter minimum stalk length was observed in the hybrid NS 43 (6.99cm) and it was on par with the hybrid NS 183 (10.00cm). NS 35 recorded a stalk length of 11.99cm and Disha was having a stalk length of 10.45cm. In open field, minimum stalk length was observed in the hybrid NS 35 (7.41cm) which was on par with all other hybrids. Disha was having a stalk length of 8.08cm followed by NS 183 (9.42) and NS 43 (10.5). (Table 4.5 and Fig 4.3)

Mean stalk length during on season in open field condition was slightly lower than that inside the rain shelter. Inside the rain shelter, minimum stalk length was observed in NS 43 (5.37cm) and it was on par with NS 35 (7.12cm). NS 183 and Disha were having a stalk length of 8.83cm and 9.51cm respectively. In open field also, minimum stalk length was found in the hybrid NS 43 with 4.20cm and it was on par with NS 35

Table 4.5. Plant spread (cm) and stalk length (cm) during off- season

Treatments	Plant spread		Stalk length	
	Polyhouse	Open field	Polyhouse	Open field
T1(NS 183)	43.30	22.16	10.00	9.42
T2(NS 43)	48.20	21.67	6.99	10.50
T3(NS 35)	39.75	17.83	11.99	7.41
T4(Disha)	41.15	22.17	10.45	8.08
Mean	43.10	20.96	9.86	8.85
CD(p<0.05)	**4.506**		**3.314**	

Table 4.6 . Plants spread (cm) and stalk length (cm) during on- season

Treatments	Plant spread		Stalk length	
	Poly house	Open field	Poly house	Open field
T1(NS 183)	58.16	55.33	8.83	8.40
T2(NS 43)	61.91	59.25	5.37	4.20
T3(NS 35)	65.41	67.66	7.12	4.97
T4(Disha)	57.08	56.75	9.15	11.17
Mean	60.64	59.75	7.62	7.18
CD(p<0.05)	**4.180**		**2.173**	

Open field crop

Rain shelter crop

Plate 9. Comparison of plant spread of off season crop

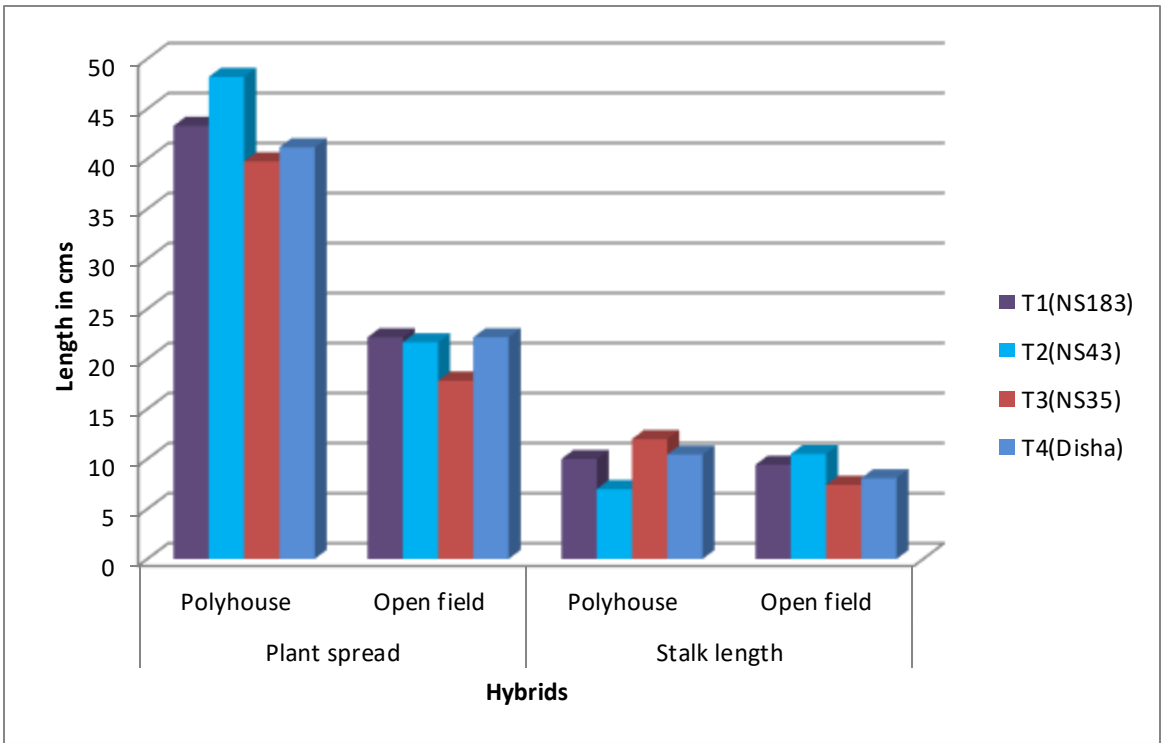


Fig 3. Plant spread (cm) and stalk length (cm) during off- season

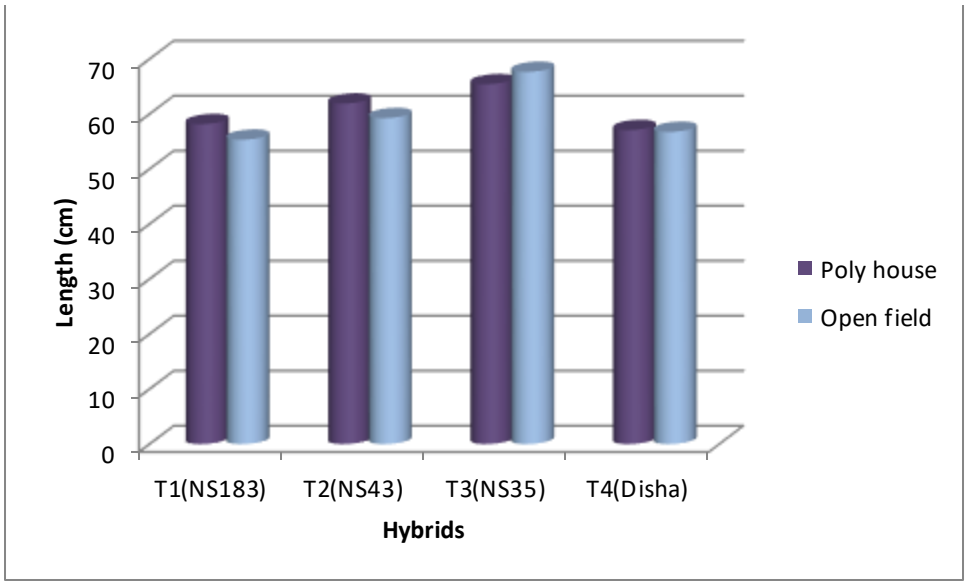


Fig .4. Plant spread as influenced by growing condition during on- season

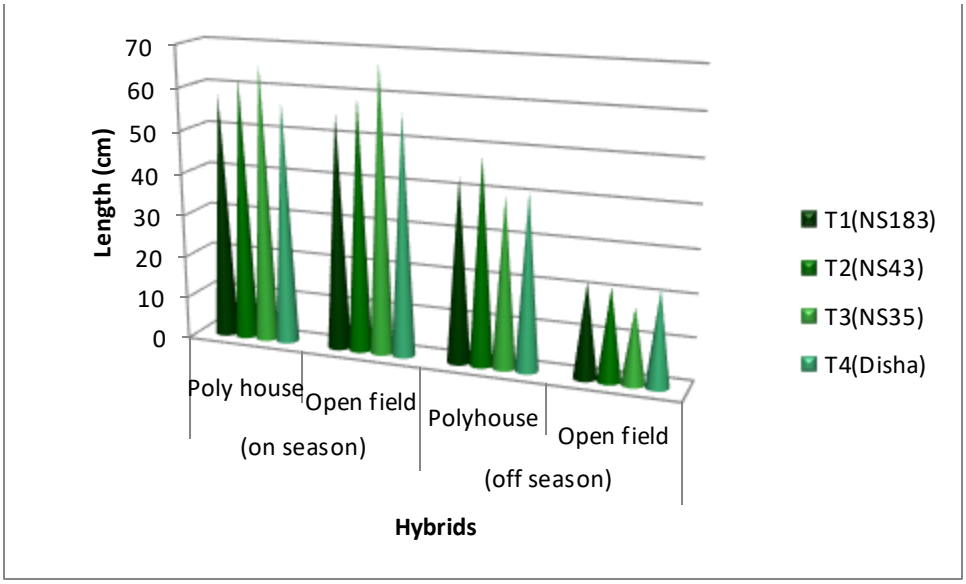


Fig 5. Plant spread as influenced by growing conditions and seasons

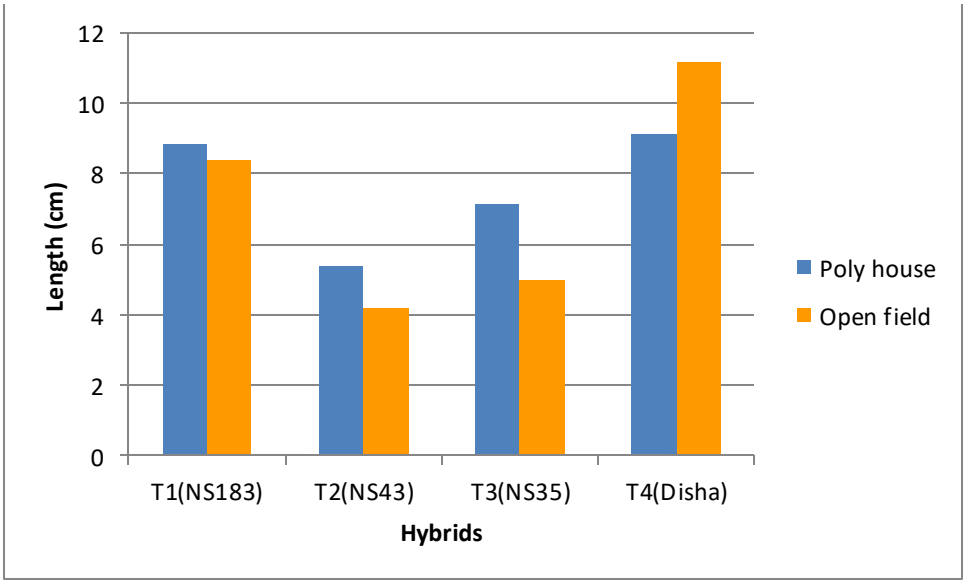


Fig 6. Comparison of stalk length of hybrids during on- season

(4.97cm). NS 183 and Disha were having a stalk length of 8.4cm and 11.17cm respectively. (Table 4.6 and Fig. 4.6)

4.2.5. Days to 50% head formation:

During off- season, minimum number of days to 50% head formation was observed in the hybrid NS 43 and it achieved 50% head formation in 52.00 days followed by NS 35(59.25), NS 183 (59.00) and Disha (58.8). (Table 4.7 and Fig 4.7)

During on- season, inside the rain shelter minimum number of days for 50% head formation was observed in the hybrid NS 43 (50.00) and was on par with NS 183 (52.00)and Disha (52.75). In the hybrid NS 35, 50% head formation was observed in 57.25 days inside the rain shelter. In open field, head formation was earlier when compared to the rain shelter during on- season. NS 43 was earliest (49.25) followed by Disha (50.25) and it was on par with NS 183 and NS 35 (52.00). Mean number of days for 50% head formation under open field condition was 50.87 and inside it was 53.00. (Table 4.8) (Fig 4.8 and 4.9).

4.2.6. Days to 50% head maturity:

During off- season, under protected condition minimum number of days to 50% head maturity was observed in the hybrid NS 43 (74.5). Hybrid NS 35 took 85 days to obtain 50% head maturity and it was on par with Disha (90.50) and NS 183 (88.25). (Table 4.7 and Fig 4.7)

During on- season also NS 43 was found to be earliest (84.75) to mature inside the rain shelter and it was on par with other hybrids. NS 183 and NS 35 took 91.75 days and 91.25 days to achieve 50% head maturity and Disha took only 89.00 days. In open field, NS 183 was found to be early (71.75) when compared to other hybrids and it was on par with Disha (72.50). From the mean number of days to obtain 50% head maturity it was evident that the open field crop was earlier than the rain shelter crop during on- season. The mean number of days inside the rain shelter was 89.19 and in open field it was 76.69. (Table 4.8) (Fig. 4.8 and 4.10) (Plate 10)

Table 4.7. Days to 50% head formation and 50% head maturity during off- season inside rain shelter

Treatments	**Days to 50%head formation**	**Days to 50% head maturity**
T1(NS 183)	59.00	88.25
T2(NS 43)	52.00	74.5
T3(NS 35)	59.25	85.00
T4(Disha)	58.80	90.50
CD (p<0.05)	**6.584**	**5.372**

Table 4.8. Days to 50% head formation and head maturity during on- season.

Treatments	**Days to 50% head formation**		**Days to 50% head maturity**	
	Polyhouse	Open field	Polyhouse	Open field
T1(NS 183)	52.00	52.00	91.75	71.75
T2(NS 43)	50.00	49.25	84.75	79.00
T3(NS 35)	57.25	52.00	91.25	83.00
T4(Disha)	52.75	50.25	89.00	72.50
Mean	53.00	50.87	89.19	76.69
CD(p<0.05)	**3.023**		**8.545**	

NS 183

NS 43

NS 35

Disha

Plate 10. Cabbage heads of the F1 hybrids at marketable stage

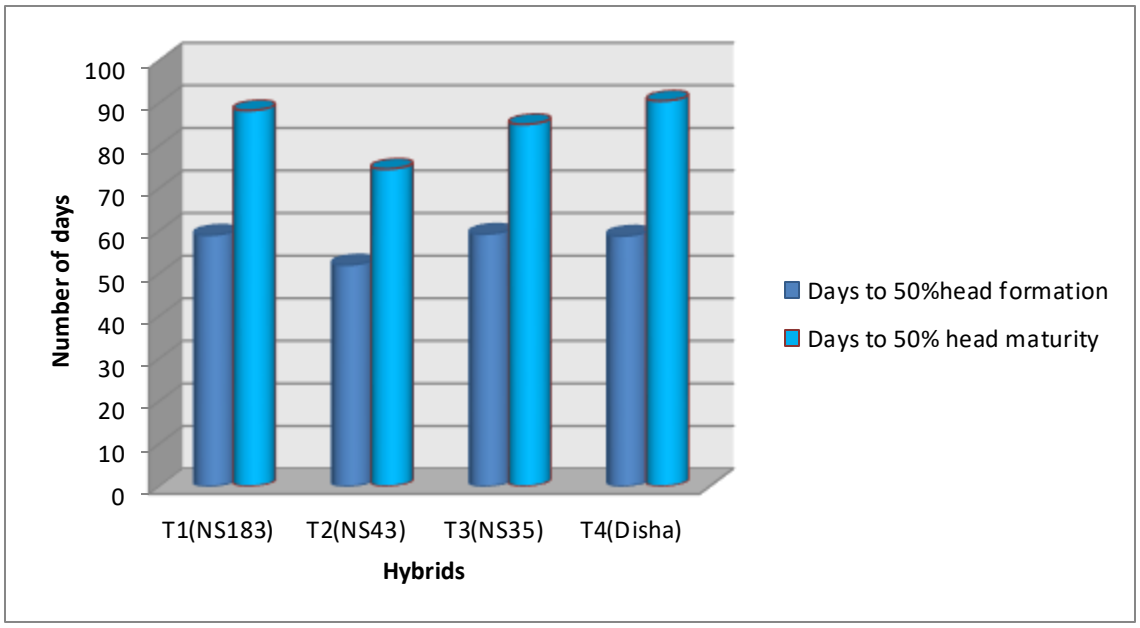


Fig 7. Days to 50% head formation and 50% head maturity of the hybrids during off- season inside rain shelter

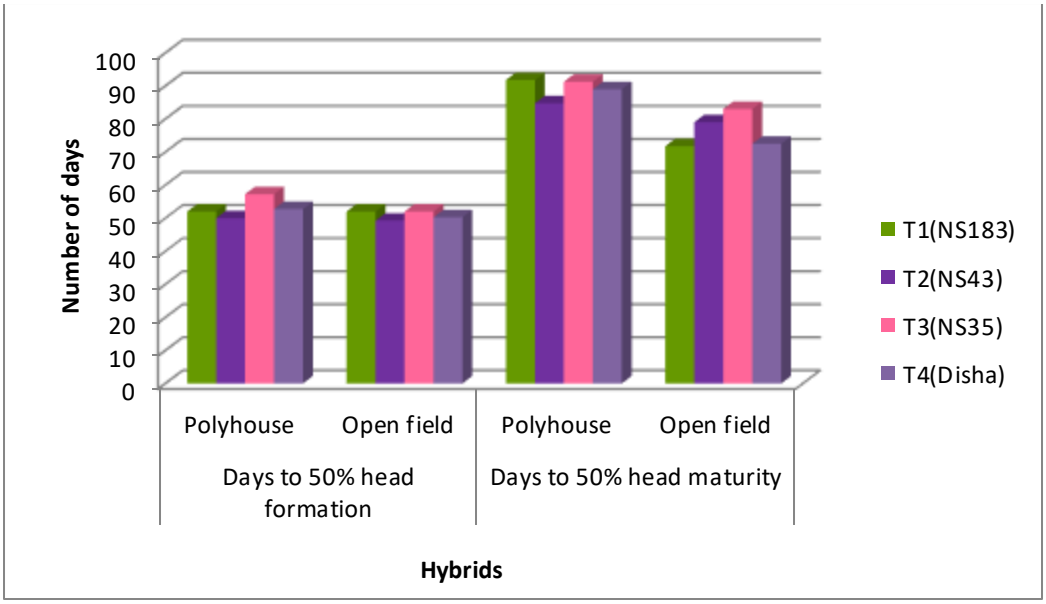


Fig .8. Days to 50% head formation and 50% head maturity during on- season.

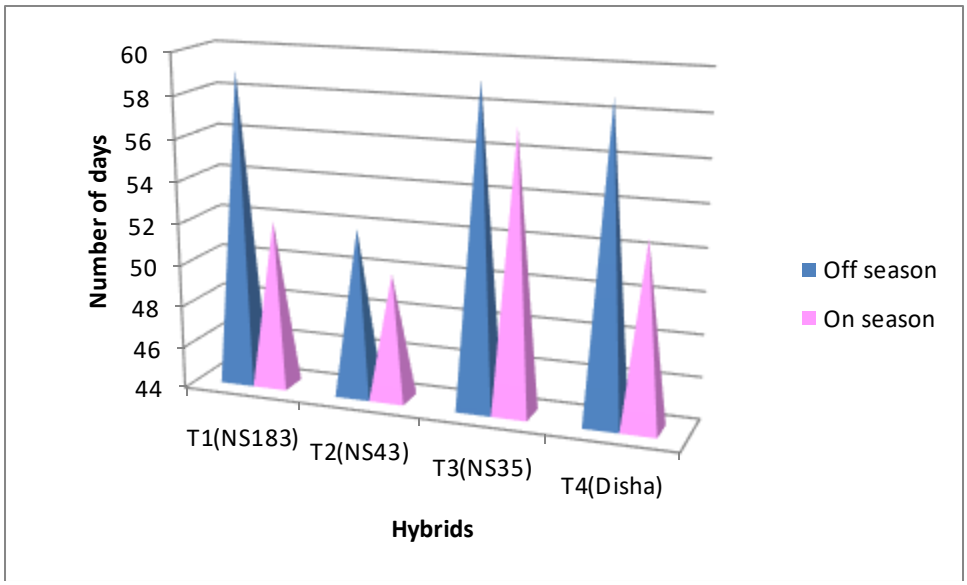


Fig 9. Days to 50% head formation inside rain shelter during both seasons

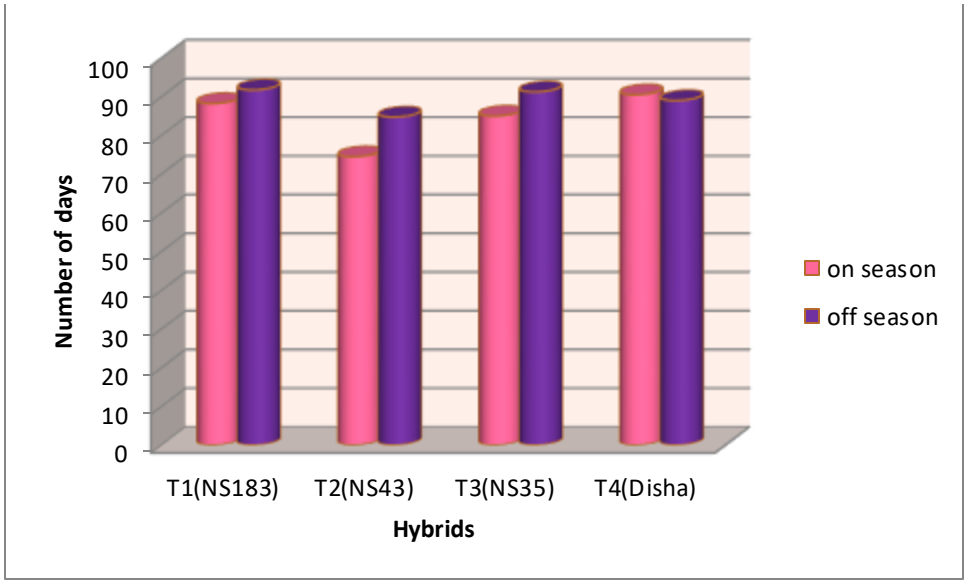


Fig.10. Days to 50% head maturity during two seasons inside rain shelter

4.2.7. Gross head weight:

It was observed that during off- season inside the rain shelter maximum gross weight was obtained for the hybrid NS 183 (986.75g) and it was on par with NS 43 (956.50g). NS 35 recorded a gross head weight of 803.75g and Disha recorded 815.25g. (Table 4.9 and Fig. 4.11)

During on- season, inside the rain shelter maximum gross weight was observed for the hybrid Disha (1655g) and it was on par with NS 35 (1597.50g). Under open condition, the hybrids showed significance for this character with respect to the growing conditions and also among the hybrids. Maximum gross weight was observed for the hybrid NS 35 (2401.00g) followed by the hybrid Disha (1847.50g) and NS 183 (1720.50g). NS 43 recorded a gross weight of 1536.00g. It was observed that the mean gross weight for the open field was higher than the protected crop during on- season. (Table 4.10) (Fig. 4.12 and 4.13)

4.2.8. Net head weight:

During off- season, maximum head weight was observed in the hybrid NS 43 (553.50g) (Plate 11.) which was on par with NS 183 (545.75g). For the hybrid Disha (T4) it was found to be 431.0g. NS 35 recorded a net head weight of 434.25g. (Table 4.9 and Fig 4.11)

The net head weight of hybrids during on- season showed that in open field the value is higher when compared to the rain shelter crop. The mean net head weight in open field was 1239.37g and inside the rain shelter it was only 1027.87g. Maximum net head weight was observed for the hybrid NS 35 (Plate 12.) in both open field condition and inside the rain shelter. Under open field condition it recorded a net head weight of 1725.00g and inside the rain shelter 1131.0g. In the open field Disha recorded a net head weight of 1110.62g and NS 183 recorded 1079.37g. NS 43 recorded a net head weight of 1042.50g. Inside the rain shelter NS 35 was on par with other hybrids. NS 183 recorded a net head weight of 1037.50g. NS 43 and Disha

Table 4.9. Gross head weight (g) and net head weight (g) inside rain shelter during off- season

Treatments	Gross head weight	Net head weight
T1(NS 183)	986.75	545.75
T2(NS 43)	956.50	553.50
T3(NS 35)	803.75	434.25
T4(Disha)	815.25	431.00
CD(p<0.05)	**169.457**	**125.367**

Table 4.10. Gross head weight (g) and net head weight (g) during on- season

Treatments	Gross head weight		Net head weight	
	Poly house	Open field	Poly house	Open field
T1(NS 183)	1556.00	1720.50	1037.50	1079.37
T2(NS 43)	1438.50	1536.00	945.50	1042.50
T3(NS 35)	1597.50	2401.00	1131.00	1725.00
T4(Disha)	1655.00	1847.50	997.50	1110.62
Mean	1561.75	1876.25	1027.87	1239.37
CD(p<0.05)	**330.244**		**264.300**	

Plate 11. NS 43 (Maximum net head weight among the hybrids during off- season)

Plate 12. NS 35 (Maximum net head weight during on- season)

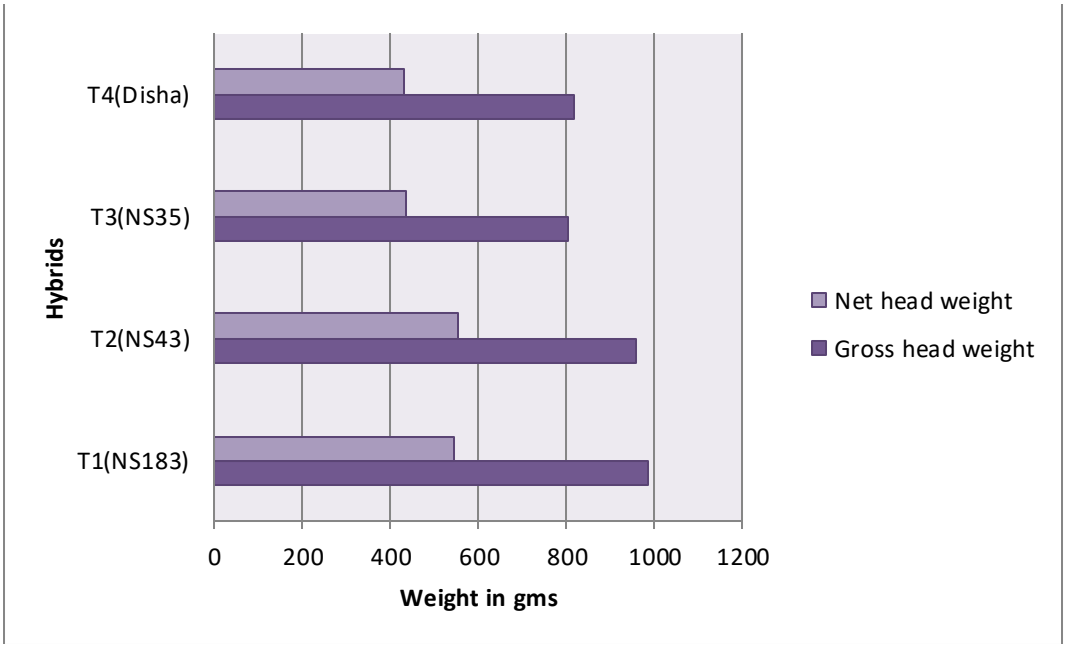


Fig 11. Gross head weight and net head weight (in grams) of the hybrids inside rain shelter during off- season

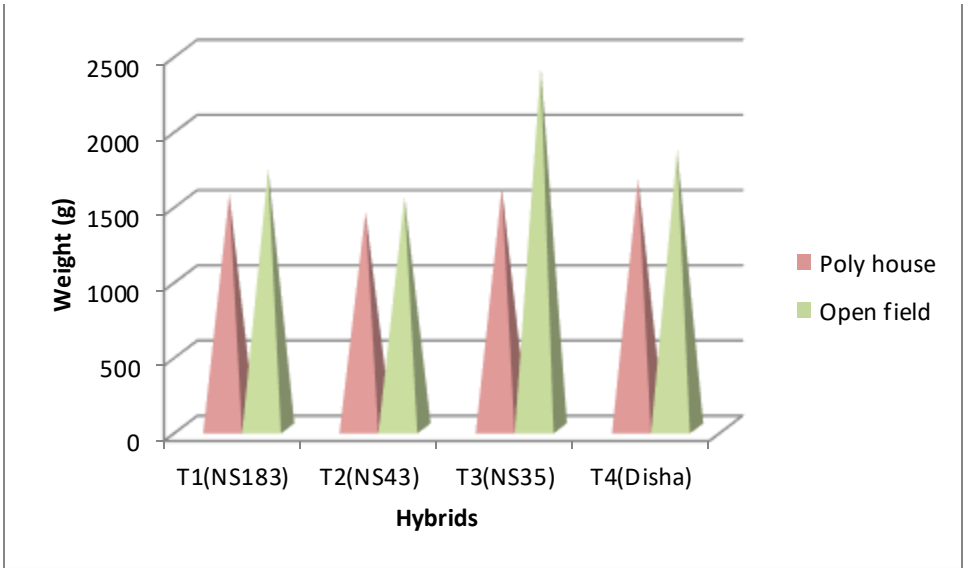


Fig 12. Gross head weight during on- season

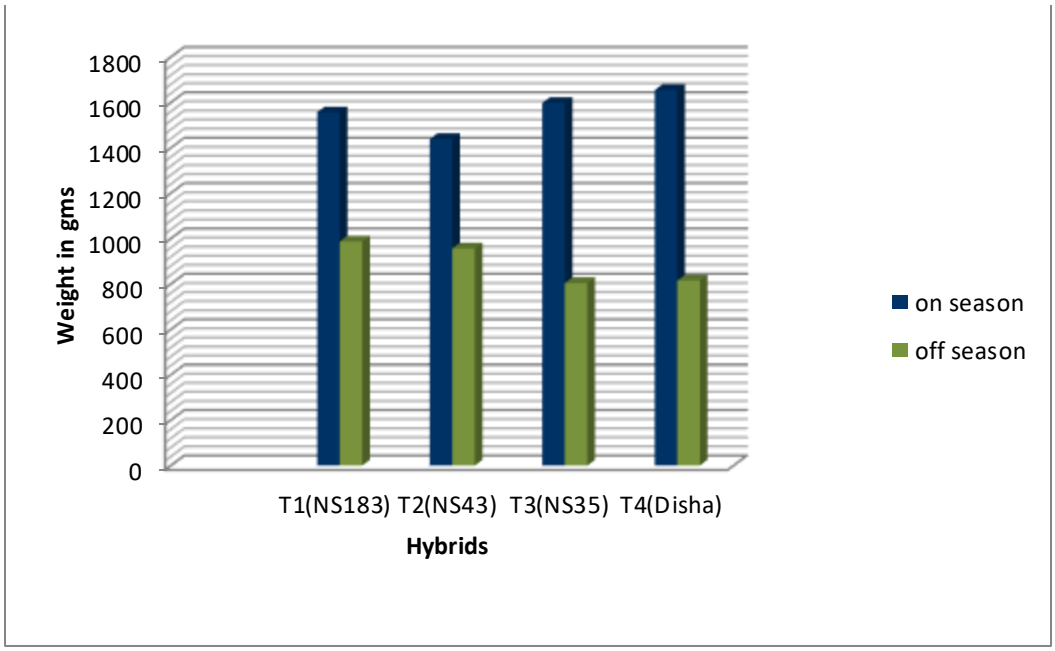


Fig13. Gross weight during on and off- seasons inside rain shelter

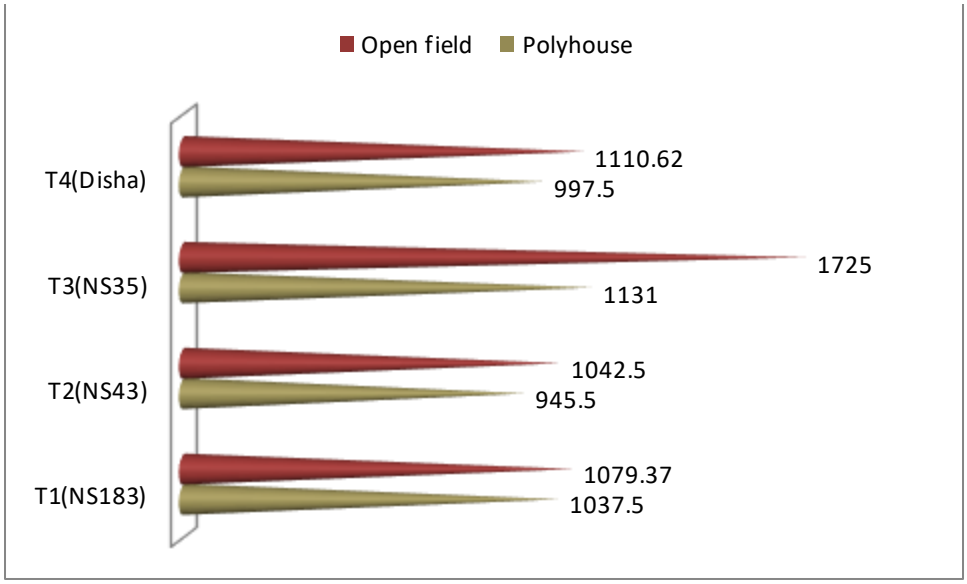


Fig 14. Net head weight during on- season

recorded a net head weight of 945.50g and 997.50g respectively. (Table 4.10 and Fig 4.14)

4.2.9. Head length:

During off- season, inside the rain shelter maximum head length was observed for the hybrid Disha (14.26cm) and it was on par with NS 183 (13.93cm). NS 35 recorded a head length of 11.97cm and NS 43 recorded a length of 13.00cm. (Table 4.11 and Fig. 4.15)

During on- season also, Disha recorded maximum head length inside the rain shelter (16.25cm) and it was on par with NS 183 (15.92cm) and NS 35 (15.54cm). Under open conditions, NS 35 recorded maximum head length of 16.91cm and it was on par with Disha (15.29cm). NS 43 was found to have a head length of 13.49cm and NS 183 recorded 14.83cm. The mean head length inside the rain shelter was 15.59cm and that of outside crop was 15.13cm respectively. (Table 4.12 and Fig 4.16)

4.2.10. Head breadth:

During off- season, inside rain shelter maximum value for head breadth was recorded for the hybrid NS 43 (14.05cm). NS 35 and NS 183 were having 10.53cm and 10.72cm of head breadths respectively. Disha recorded a head breadth of 9.75cm. (Table 4.11 and Fig. 4.15)

Maximum head breadth during on- season crop was observed for the hybrid NS 35 under open condition (17.66cm) and inside the rain shelter it was highest in NS 43 (15.46cm). Inside rain shelter it was on par with other hybrids. NS 183 recorded 14.67cm, followed by NS 35 (14.87cm) and Disha (14.58cm).(Table 4.12 and fig 4.17)

Table 4.11. Head length (cm), head breadth (cm) and core length (cm) inside rain shelter during off- season.

Treatments	Head length	Head breadth	Core length
T1(NS 183)	13.93	10.53	8.60
T2(NS 43)	13.00	14.05	6.92
T3(NS 35)	11.97	10.72	7.52
T4(Disha)	14.26	9.75	8.28
CD(p<0.05)	**0.888**	**1.557**	**1.365**

Table 4.12. Head length (cm). head breadth (cm) and core length (cm) during on-season

Treatments	Head length		Head breadth		Core length	
	Poly house	Open field	Poly house	Open field	Poly house	Open field
T1(NS 183)	15.92	14.83	14.67	14.29	8.79	8.46
T2(NS 43)	14.67	13.49	15.46	16.62	7.88	6.92
T3(NS 35)	15.54	16.91	14.87	17.67	7.87	7.37
T4(Disha)	16.25	15.29	14.58	14.83	9.16	8.33
Mean	15.59	15.13	14.87	15.85	8.43	7.77
CD(p<0.05)	**1.010**		**0.922**		**1.190**	

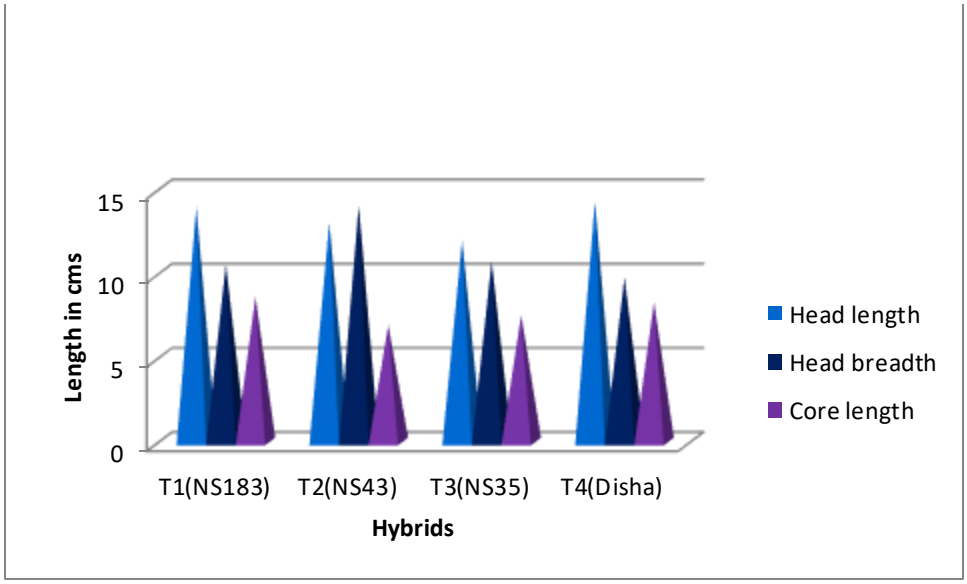


Fig 15. Head length, head breadth and core length of hybrids inside rain shelter during off- season.

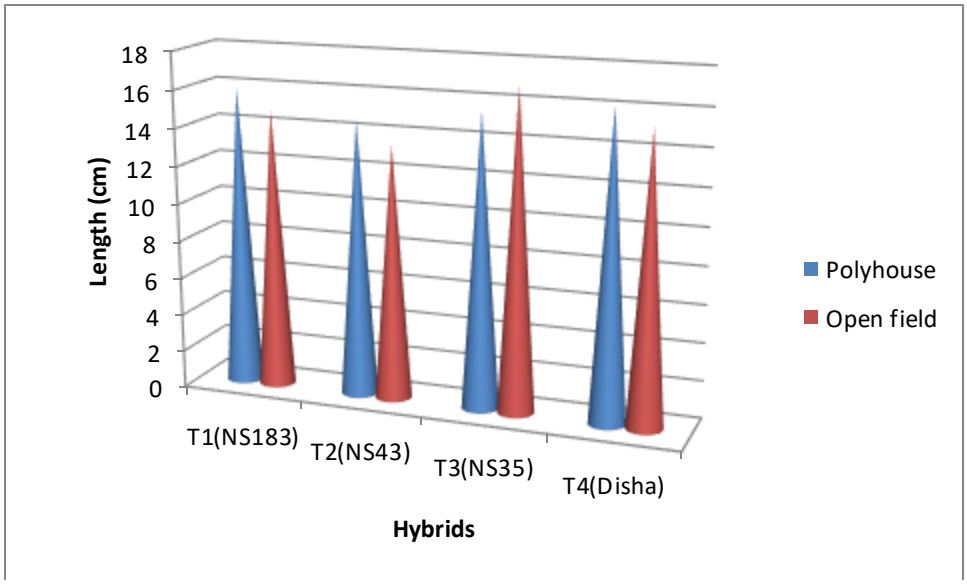


Fig 16. Head length of the hybrids during on- season

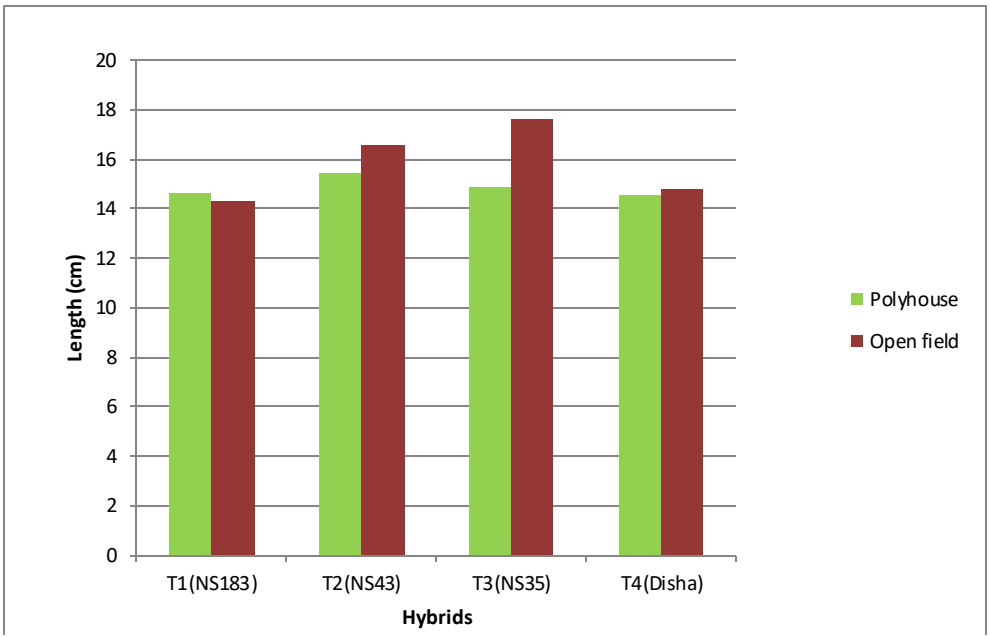


Fig 17. Head breadth of the hybrids during on- season

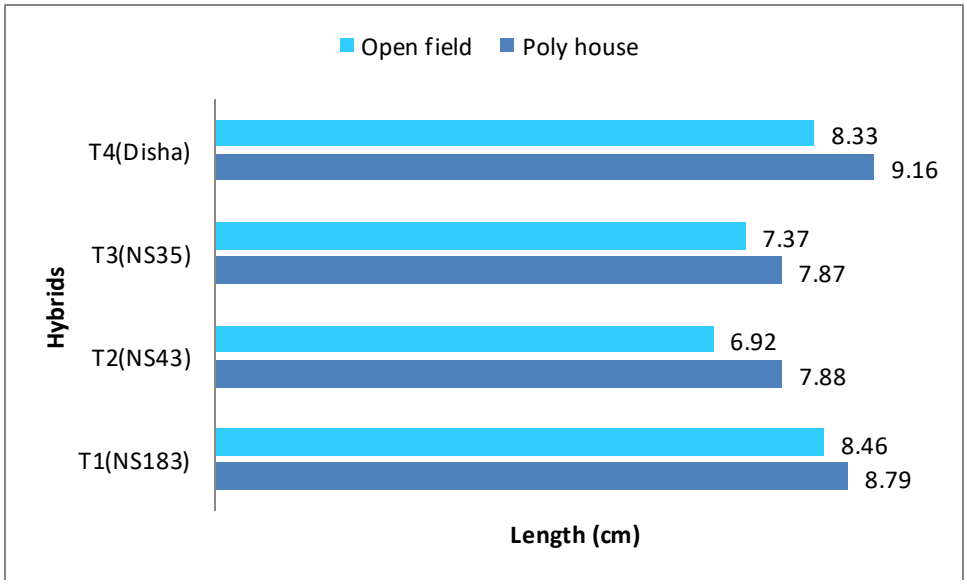


Fig 18. Core length of the hybrids during on- season

4.2.11. Core length:

During off- season, inside the rain shelter minimum core length was observed for NS 43 (6.92cm) and it was on par with NS 35 (7.52cm) and Disha (8.28cm). NS 183 recorded 8.60cm inside rain shelter. (Table 4.11 and Fig. 4.15)

Core length inside the rain shelter during on- season was minimum for NS 43(7.87cm) and it was on par with NS 183 (8.79cm) and NS 35 (7.87cm). Disha recorded a core length of 9.16cm inside the rain shelter during on- season. Under open conditions also NS 43 was having minimum core length of 6.92cm and it was on par with NS 35 (7.37cm). Disha was having a core length of 8.33cm and NS 183 (8.46cm). Mean core length of outside crop was found to be lower than that of rain shelter crop. Mean core length inside the rain shelter was 8.43cm and that under open condition was 7.77cm. (Table 4.12 and Fig 4.18) (Plate 13.)

4.2.12. Head index:

During off- season, NS 183 recorded a head index of 1.34. NS 43 was having a head index value of 0.92 and NS 35 had 1.12. Disha showed a head index of 1.48 inside the rain shelter. (Table 4.13 and Fig 4.19)

During on- season, inside the rain shelter NS 183 recorded a head index of 1.09 and 1.03 under open filed condition. For NS 43, it was 0.95 inside rain shelter and 0.82 under open field. NS 35 recorded a value of 1.02 inside rain shelter and 0.95 under open field and for Disha the value was 1.11 inside rain shelter and 1.03 under open field condition. (Table 4.14)

4.2.13. Harvest index:

During off- season, inside the rain shelter harvest index was found to be maximum for NS 43 (67.70) which was on par with NS 183 (60.46). NS 35 recorded a harvest index of 55.65 and Disha recorded a harvest index of 55.01. (Table 4.13 and Fig. 20)

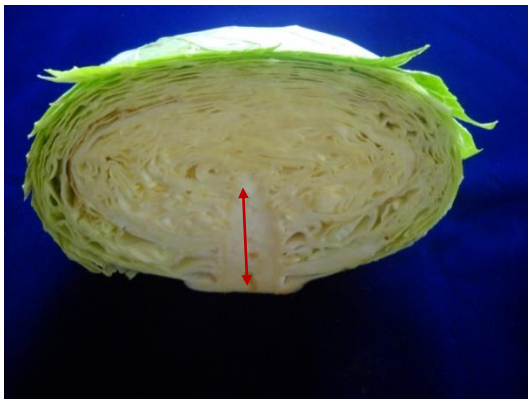
Table 4.13. Total number of marketable heads, head index and harvest index inside the rain shelter during off- season.

Treatments	**Total number of marketable heads**	**Head index**	**Harvest index**
T1(NS 183)	7.00	1.34	60.465
T2(NS 43)	8.75	0.92	67.700
T3(NS 35)	8.00	1.12	55.655
T4(Disha)	6.75	1.48	55.010
CD(p<0.05)	**NS**	**0.197**	**9.755**

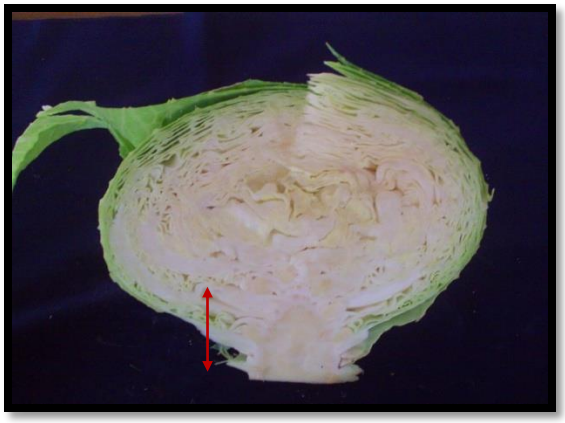
Table 4.14. Head index, harvest index and total number of marketable heads during on- season

Treatment	**Head index**		**Harvest index**		**Total no. of marketable heads**	
	Poly house	Open field	Poly house	Open field	Poly house	Open field
T1(NS 183)	1.09	1.03	66.50	63.25	7.50	7.25
T2(NS 43)	0.95	0.82	65.00	67.50	7.75	6.00
T3(NS 35)	1.02	0.95	70.75	72.00	7.25	7.75
T4(Disha)	1.11	1.03	60.00	60.00	7.50	7.75
Mean	1.04	0.96	65.56	65.68	7.50	7.18
CD(p<0.05)	**0.085**		**5.55**		**NS**	

NS 183



NS 43



NS 35

Disha

Plate 13. Core lengths of the four F1 hybrids

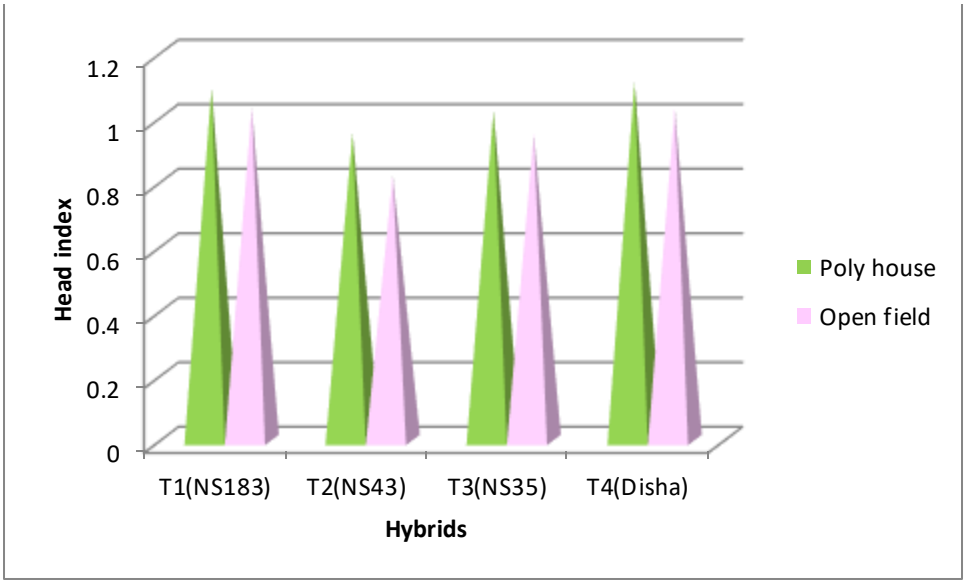


Fig 19. Head index of the hybrids during on- season

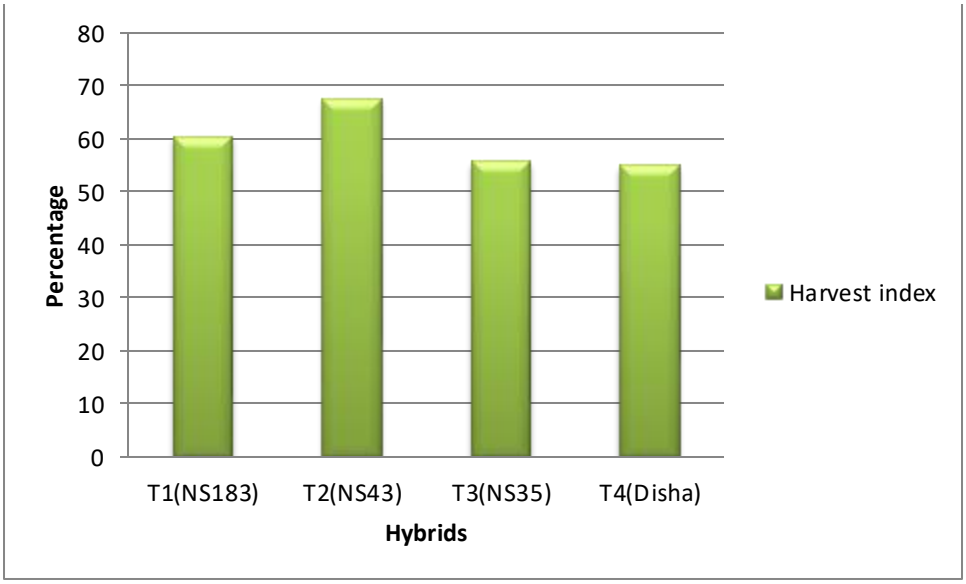


Fig 20. Harvest index inside the rain shelter during off- season

During on- season, maximum harvest index was observed for NS 35 under rain shelter and open field. Harvest index for NS 35 was 72.00 in open field and 70.75 inside rain shelter. Inside the rain shelter NS 35 was on par with NS 183. NS 183 recorded a harvest index value of 66.50 inside the rain shelter and 63.25 in open field. In open condition NS 35 was on par with NS 43 (67.50). NS 43 recorded a value of 65.00 inside the rain shelter. Disha recorded a harvest index value of 60.00 both inside rain shelter and in open field. (Table 4.14 and Fig 4.21)

4.2.14. Total number of marketable heads:

The hybrids did not differ significantly for the character observed during off- season and on-season under both growing conditions.

During off- season, out of the ten plants NS 43 recorded maximum number of marketable heads (8.75) followed by NS 35 (8.00), NS 183 (7.00) and Disha (6.75) inside the rain shelter. During on season also, NS 43 recorded maximum number of marketable heads (7.75) followed by NS 183, Disha (7.50) and NS 35 (7.25) inside the rain shelter. Under open field, NS 35 and Disha formed maximum number of marketable heads (7.75) followed by NS 183 (7.25) and NS 43 (6.00). (Table 4.13 and 4.14).

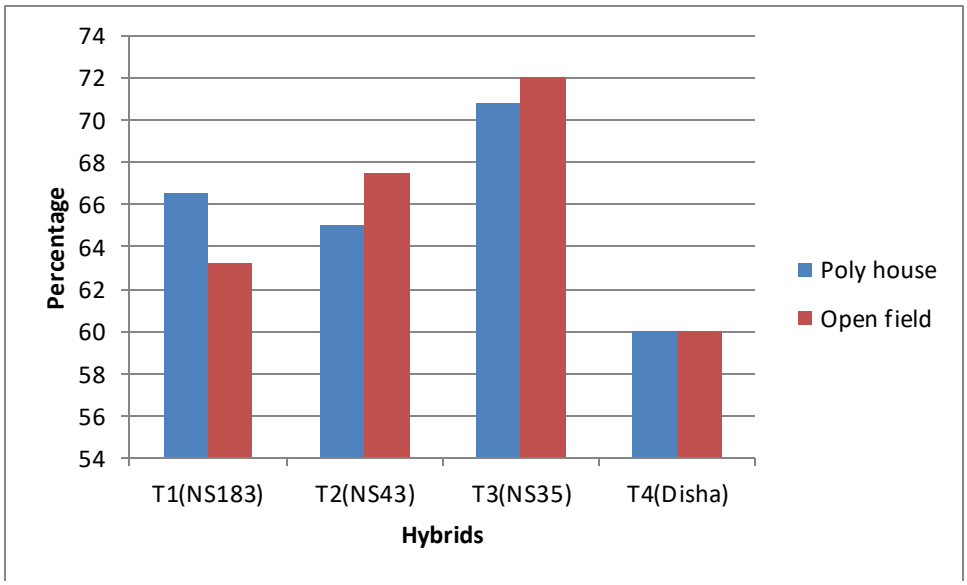


Fig 21. Harvest index during on- season

4.3. PEST AND DISEASE INCIDENCE:

4.3.1. Pest incidence

During off- season, pest incidence was more in open field. *Spodoptera litura* was the major pest found during off- season. Among the treatments lowest pest incidence was noticed in the hybrid NS 35 (2.5%) inside the rain shelter followed by Disha (7.5%), NS 183 (15%) and NS 43 (20%). Under open field conditions minimum incidence was observed in Disha (9.47%), followed by NS 35 (16.67%), NS 183 (19.46%) and NS 43 (24.95%).

During on- season also, incidence was more in open field and rain shelter. During on- season also, *Spodoptera litura* was the major pest attacking the crop. Besides this, other pests like leaf webber (*Crocidolomia binotalis*) and painted bug (*Bugrada hilaris*) were also observed. Inside the rain shelter pest attack was found to be lowest for NS 43 and NS 35 (17.5%) and highest for NS 183 (25%). Under open field pest attack was very high and maximum in NS 43 (47.5%). All the treatments showed high pest incidence under open field condition. However, in NS 35 (30%) it was slightly lower when compared to the other treatments. The percentage incidence of pest during both seasons is shown in Table 4.15.

4.3.2. Disease incidence:

During nursery stage damping off was noticed for all the treatments but it was controlled. During off- season, disease incidence was more under open field conditions and from the percentage incidence worked out it was observed that Disha recorded highest (49.7%) incidence followed by NS 35 (48.06%). It was minimum for NS 43 (38.81%). Head rot (*Alternaria brassicae*) was observed during off- season under open condition. Inside the rain shelter minimum incidence was observed in NS 183 (2.5%) followed by Disha (15%), NS 43 (17.5%) and maximum in NS 35 (25%).

During on- season, no major disease incidence was noticed both under rain shelter and in open field. However, some incidence of *Alternaria* leaf spot was observed both inside and outside rain shelter. The percentage incidence of diseases during both seasons is shown in Table 4.15.

Table 4.15. Pest and disease incidence (%) during off- season and on- season

Treatment	**Pest incidence**				**Disease incidence**			
	Off- season		**On- season**		**Off- season**		**On- season**	
	Polyhouse	Open field	Polyhouse	Open field	Polyhouse	Open field	Polyhouse	Open field
T1(NS 183)	15	19.46	25	45	2.5	46.88	0	0
T2(NS 43)	20	24.95	17.5	47.5	17.5	38.81	0	0
T3(NS 35)	2.5	16.67	17.5	30	25	48.06	2.5	0
T4(Disha)	7.5	9.47	22.5	42.5	15	49.7	0	2.5

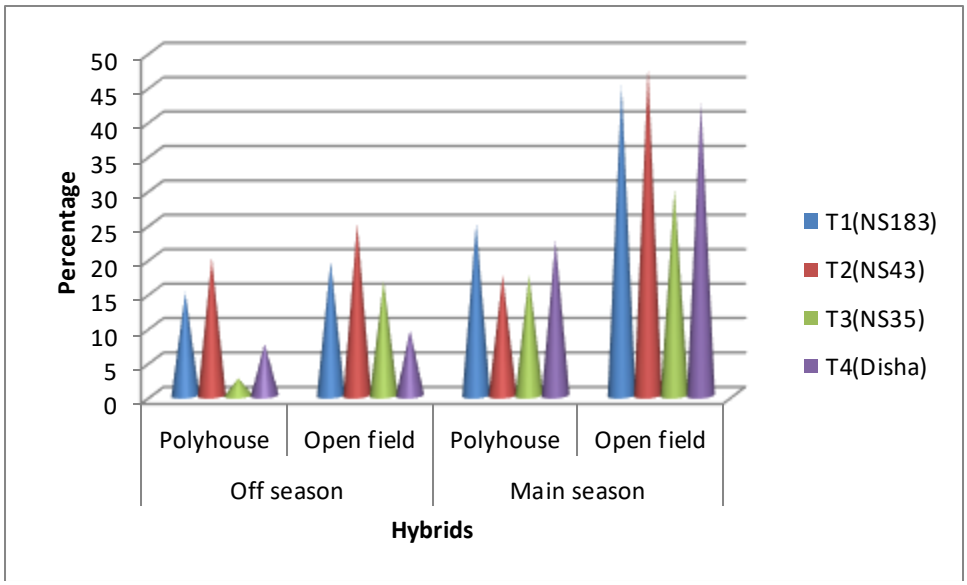


Fig 22. Pest incidence during on and off- seasons

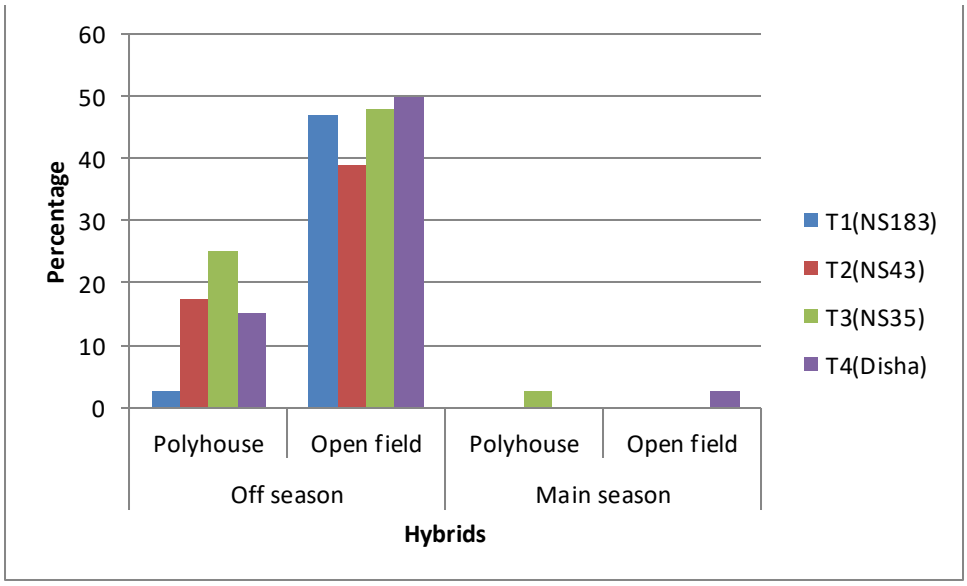


Fig 23. Disease incidence during on and off- seasons

4.4. CROP WEATHER CORRELATION STUDIES:

Simple correlation between important plant characters viz, days to 50% head formation, days to 50% head maturity, and yield /harvest with weather parameters like maximum temperature, minimum temperature, relative humidity at morning and noon and rainfall for different growing conditions was computed and correlation coefficients are presented in the tables 4.16 and 4.17

4.4.1. Off- season crop:

Inside the rain shelter, days to fifty percent head formation was positively correlated with maximum temperature and relative humidity at morning while it showed negative correlation with minimum temperature and relative humidity at noon. Days to fifty percent head maturity is positively correlated with minimum temperature and negatively correlated with relative humidity at noon. Yield per harvest showed negative correlation with minimum temperature while it was positively influenced by relative humidity at noon.

4.4.2. On- season crop:

Inside the rain shelter, days to fifty percent head formation showed significant correlation with all the weather parameters recorded. It was positively correlated with minimum temperature and relative humidity at noon while negatively affected by the maximum temperature and relative humidity at morning. Days to fifty percent head maturity also showed significant positive correlation with minimum temperature and relative humidity (at morning and noon) while it was negatively influenced by maximum temperature.

Under open field conditions, days to fifty percent head formation was negatively correlated with maximum temperature and relative humidity at morning and it showed positive correlation with minimum temperature and relative humidity at noon. Days to fifty percent head maturity showed positive correlation with maximum temperature, relative humidity (at noon and morning) while it was negatively correlated with minimum temperature.

Table 4.16 Simple correlation of plant characters during off- season with weather parameters

Plant Character	Maximum temperature		Minimum temperature		Relative humidity(morning)		Relative humidity(noon)		Rainfall	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
Days to 50% head formation	-	0.9986**	-	-0.9986**	-	0.9986**	-	-0.9986**	-	NA
Days to 50% head maturity	-	0.0456	-	0.9347**	-	-0.1645	-	-0.7931**	-	NA
Yield/harvest	-	0.5367	-	-0.6536	-	0.7486	-	0.0121	-	NA

Table4.17. Simple correlation of plant characters during on- season with weather parameters

Plant Character	Maximum temperature		Minimum temperature		Relative humidity(morning)		Relative humidity(noon)		Rainfall	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
Days to 50% head formation	-0.6445*	-0.9253**	0.6445*	0.9253**	-0.6445*	-0.9253**	0.6445*	0.9253**	-	
Days to 50% head maturity	0.8127**	-0.9271**	-0.9250	0.9270**	0.9860**	0.9270**	0.5949*	0.9270**	-	
Yield/harvest	-0.2522	0.3916	-0.1202	0.2468	0.1843	0.4290	0.4168	0.2429	-0.3171	NA

Yield per harvest showed no correlation with any of these weather parameters during on-season under both growing conditions.

However, a better comparison between the weather parameters and plant characters can be obtained from tables 4.18 to 4.21. From the tables 4.18 and 4.19 it was evident that during off- season inside the rain shelter 50% head formation was first observed for the hybrid NS 43 during 43rd standard week with maximum and minimum temperature of 30.5^{0}C and 25.5^{0}C respectively. Relative humidity at morning and noon were 70% and 35%respectively. All other hybrids recorded 50% head formation in 44th standard week with maximum and minimum temperature 32.4^{0}C and 19.9^{0}C and relative humidity at morning and noon were 73% and 31% while under open field condition, maximum temperature was slightly lower than the rain shelter condition during this time (43rd week- 29.3^{0}C and 44th week-30.6^{0}C).

From the table 4.18 it is clear that relative humidity was very high in open field during off-season during the time of 50% head formation (43rd week-94%(morning) and 76%(noon), 44th week- 95%(morning) and 71%(noon)). Rainfall is an additional weather parameter which influenced the open field crop while rain shelter crop was protected. Open field crop received a rainfall of 13.4mm and 22mm during 43rd and 44th weeks. Fifty percent head formation was not observed under open field till the end of the season.

Days to 50% head maturity was obtained inside the polyhouse during the standard weeks 47, 48, and 49. During this period maximum temperature ranged between 29.2-33^{0}C, minimum temperature ranged between 19.8-20.2^{0}C and RH (morning ranges between 61-75% and RH (noon) ranges between 23-31% inside the rain shelter. In open field also, maximum and minimum temperature during these weeks came under this range but relative humidity was high and it ranged between 83-91% (morning) and 59-71% (noon). Rainfall during this period ranged between 0.3mm to 8.7mm.

Rain shelter crop was first harvested during 45th standard week while the open field crop was first harvested during 47th standard week . Yield per harvest and numbers of harvests were higher for the rain shelter crop during off- season and from open field marketable heads were not obtained during off- season. Here also there was high variation in the relative humidity of the two growing conditions.

Table 4.18. Comparison between weather parameters and plant characters during off- season in open field.

Standard week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %	Rainfall (mm)	Days to 50% HF	Days to 50% HM	Yield/hvst (g)	No: of NWL	No: of WL	Plant Spread (cm)	Stalk length (cm)	Gross Wt (g)	Net Wt (g)	HL (cm)	HB (cm)	CL (cm)	Head Index	HI	Total No.of MH
26	30.2	23.1	96	76	28.6															
27	28.6	22.8	96	81	26.6															
28	31.2	24	95	72	33.2															
29	27.8	30	97	84	23.9															
30	29.6	22.3	95	81	14.8															
31	28.6	22.3	96	74	19.2															
32	30.6	24.1	95	73	4.4															
33	29.5	23	94	79	6.2															
34	28.7	23.3	94	83	1.9															
35	28.6	22.8	95	76	9.1															
36	29.9	23.1	94	73	5.6															
37	29.8	23.2	96	72	21.2															
38	30.2	23	95	72	8.1															
39	31.9	23	92	68	10.8															
40	30.6	22.7	95	78	41.4															
41	29.5	23.3	74	70	5.1															
42	28.3	21.9	95	78	18.6															
43	29.3	27.3	94	76	13.4															
44	30.6	22.2	95	71	22															
45	30.4	22.3	96	73	17															
46	31.3	22.5	92	67	8.5															
47	30.8	22.5	91	71	8.7			166.67	13	6.16	22.16	9.42								
48	28.1	22.8	83	71	1.2				9.42	3.91	21.67	10.50								
49	31	21.3	89	59	0.3				10.25	6.08	17.83	7.41	50% head formation was not observed till the end of season.							
50	31.4	21.5	91	59	0.4			176.56	14.73	4.99	22.17	8.08								

Table 4.19. Comparison between weather parameters and plant characters during off- season inside polyhouse

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %	Rain fall (mm)	Days to 50% HF	Days to 50% HM	Yield/ hvst (g)	No: of NWL	No: of WL	Plant Spread (cm)	Stalk length (cm)	Gross Wt (g)	Net Wt (g)	HL (cm)	HB (cm)	CL (cm)	Head Index	HI	Total No. of MH
26	32.1	22.8	80	34	NA															
27	29.9	21.7	78	36	NA															
28	33.4	22.3	76	30	NA															
29	30.1	22.5	76	33	NA															
30	32.2	22.1	79	29	NA															
31	34.3	23.5	81	26	NA															
32	32.6	21.5	78	32	NA															
33	29.5	21.1	78	33	NA															
34	30.2	22.4	82	29	NA															
35	30.2	21.9	84	28	NA															
36	30	21.4	79	27	NA															
37	32.8	21.8	77	24	NA															
38	33.5	20.9	76	21	NA															
39	34.1	24.1	75	21	NA															
40	32.1	20.7	71	36	NA															
41	32.8	21.4	37	32	NA															
42	29.9	20.1	72	38	NA															
43	30.5	25.5	70	35	NA	52(T2)														
44	32.4	19.9	73	31	NA	58.8(T4)														
45	31.8	20.2	81	33	NA	59(T1)		573.88												
46	33.2	19.5	76	29	NA	59.25(T3)														
47	32.6	19.8	75	31	NA		74.5(T2)	431.67	7.4	4.0	48.2	6.99	956.5	553.5	13.	14.05	6.92	0.92	67.7	8.75
48	29.2	20	61	31	NA		85(T3)	325	7.5	4.3	39.75	11.99	803.7	434.2	11.9	10.72	7.52	1.02	55.6	8
49	33	20.2	64	23	NA		88.25(T1)	461.12 471.542 9.62	11.7	4.7	43.30	10.00	986.7	545.7	13.9	10.53	8.60	1.34	60.6	7
50	32.9	20.4	78	22	NA		90.50(T4)	305.71	10.6	4.7	41.15	10.45	815.2	431	14.2	9.75	8.28	1.48	55.0	6.75

All other observations were also recorded in a period between 47th week and 50th week for both the crops.

During on- season, inside the rain shelter and in the open field 50% head formation was first observed during 3rd standard week. NS 43, NS 183, and Disha formed 50% heads in this week. NS 35 formed 50% heads in 4th standard week under both growing conditions. In the 3rd standard week, maximum temperature ranged between 32.9^{0}C and 33.8^{0}C in two growing conditions, minimum temperature between 19.2^{0}C and 20.9^{0}C. Here also, there was a variation in the relative humidity values inside the rain shelter and open field. Inside rain shelter it was lower (morning-38% and noon 18%) and outside it was 73% (morning) and 36% (noon). There was no rainfall during this week.

Open field crop achieved 50% head maturity earlier than the rain shelter during on- season. In open field, NS 183 and Disha attained 50% head maturity during 5th standard week while inside rain shelter they achieved 50% head maturity during 8th standard week. During 5th standard week the maximum temperature was 33.4^{0}C, minimum temperature- 22.9^{0}C, relative humidity at morning was 61% and at noon 29% respectively. Inside the rain shelter the weather parameters during the 8th standard week were maximum temperature-34.9^{0}C, minimum-20.3^{0}C, relative humidity (morning)-75%. NS 43 achieved 50% head maturity in open field in 6th standard week and inside rain shelter in 7th standard week. NS 35 was the late to achieve 50% maturity under both growing conditions. There was no rainfall during the period of 50% head maturity i.e. from 5th -8th standard week.

Yield per harvest was higher for open field crop than the rain shelter crop during on- season in almost all harvests. The crop was harvested from 3rd standard week to 8th standard week both inside and outside rain shelter. From the table 4.18 it was clear that during off- season the open field crop received a rainfall ranging from 0.4mm to 41.4mm while during on- season there was no rainfall. There was a wide difference in the relative humidity values in the two seasons.

Under the open field condition all the other observations were recorded in the standard weeks 5, 6 and 7 while in rain shelter it was recorded in 7th and 8th standard week.

Table 4.20.Comparison between weather parameters and plant characters during on- season under open conditions

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %	Rain fall (mm)	Days to 50% HF	Days to 50% HM	Yield/ hvst (g)	No: of NWL	No: of WL	Plant Spread (cm)	Stalk length (cm)	Gross Wt (g)	Net Wt (g)	HL (cm)	HB (cm)	CL (cm)	Head Index	HI	Total No. of MH
40	30.6	22.7	95	78	41.4															
41	29.5	23.3	74	70	5.1															
42	28.3	21.9	95	78	18.6															
43	29.3	27.3	94	76	13.4															
44	30.6	22.2	95	71	22															
45	30.4	22.3	96	73	17															
46	31.3	22.5	92	67	8.5															
47	30.8	22.5	91	71	8.7															
48	28.1	22.8	83	71	1.2															
49	31	21.3	89	59	0.3															
50	31.4	21.5	91	59	0.4															
51	30.9	22.8	77	55	2.6															
52	30.7	21.8	76	51	0															
1	31.9	22.3	84	51	0															
2	33.2	22.3	89	45	0															
3	32.9	20.9	73	36	0	49.25(T2) 50.25(T4) 50.00(T1)		725												
4	32.2	22.9	67	38	0	52.00(T3)		961												
5	33.4	22.9	61	29	0		72.50(T4) 71.25(T1)	905 1066.9	14.6 16.0	4.5 4.9	56.75 55.33	11.1 8.4	1847.5 1720.5	1110.6 1079.3	15.2 14.8	14.83 14.29	8.33 8.46	1.03 1.03	60 63.2	7.7 7.2
6	34.2	21	68	27	0		79(T2)	1171.2	9.33	4.1	59.25	4.2	1536	1042.5	13.4	16.62	6.92	0.82	67.5	6
7	33.9	21.2	75	35	0		83.00(T3)	1100	9.5	5.2	67.66	4.9	2401	1725	16.9	17.67	7.37	0.95	72	7.7
8	33.5	22.7	90	52	0			1300 1333.3												
9	33.7	23	73	36	0			890												

Table 4.21. Comparison between weather parameters and plant characters during on- season inside rain shelter

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %	Rain fall (mm)	Days to 50% HF	Days to 50% HM	Yield/hvst (g)	No: of NWL	No: of WL	Plant Spread (cm)	Stalk length (cm)	Gross Wt (g)	Net Wt (g)	HL (cm)	HB (cm)	CL (cm)	Head Index	HI	Total No. of MH
40	32.1	20.7	71	36	NA															
41	32.8	21.4	37	32	NA															
42	29.9	20.1	72	38	NA															
43	30.5	25.5	70	35	NA															
44	32.4	19.9	73	31	NA															
45	31.8	20.2	81	33	NA															
46	33.2	19.5	76	29	NA															
47	32.6	19.8	75	31	NA															
48	29.2	20	61	31	NA															
49	33	20.2	64	23	NA															
50	32.9	20.4	78	22	NA															
51	32	20.8	36	23	NA															
52	32.1	19.9	34	21	NA															
1	33.1	19.8	62	21	NA															
2	34.2	19.9	68	19	NA	50.00(T2)														
3	33.8	19.2	38	18	NA	52.00(T1) 52.75(T4)		635												
4	34	20	32	15	NA	57.25(T3)		842.5												
5	34.8	20.5	31	16	NA			675												
6	35.5	19.5	31	28	NA			660												
7	35.6	20	38	19	NA		84.75(T2)	1025	9.0	4.6	61.9	5.37	1438.5	945.5	14.6	15.46	7.8	0.95	65	7.75
8	34.9	20.3	75	36	NA		89(T4) 91.25(T3) 91.75(T1)	1150 904.8 862.14	12.5 10.0 9.0	5 4.6 4.3	57.08 65.41 58.16	9.15 7.12 8.83	1655.0 1597.5 1556.0	997.50 1131.0 1037.5	16.2 15.5 15.9	14.58 14.87 14.67	9.16 7.87 8.79	1.11 1.02 1.09	60 70.7 66.5	7.5 7.25 7.5
9	34.8	20.4	37	35	NA															

4.5. BENEFIT- COST RATIO:

During off- season inside the rain shelter, the total cost for cultivation (including the construction cost and interest on fixed capital) was recorded as Rs. 48.30 per m^2 and the total benefit was Rs.55.12 per m^2. Benefit –cost ratio of the rain shelter crop during the off- season was 1.14. In the open field, as none of the plants formed marketable heads benefit- cost ratio could not be calculated.

During on- season, the total cost for cultivation (including construction cost and interest on fixed capital) was recorded as Rs. 47.90 per m^2 and the total benefit was Rs. 58.80 per m^2 inside the rain shelter. B: C ratio calculated was 1.02 inside the rain shelter. Under open field conditions, the total cost of cultivation was Rs.23.00 per m^2 and the total benefit was Rs.61.18 per m^2 and B: C ratio was 2.66. (Table 4.22)

Table 4.22. Comparison of Benefit – cost ratio of the crops cultivated under protected and open field during on and off- seasons.

Seasons	Growing conditions	
	Polyhouse	Open field
Off- season (July-Oct)	1.14	-
On- season (Oct-Jan)	1.02	2.66

Discussion

5. DISCUSSION

Greenhouse technology is considered as an appropriate intervention in the development of horticulture in India. This technology is based on the principle that productivity of a crop is influenced not only by its heredity but also by the microclimate around it (Choudhary and Shukla, 2004).

Among the different kinds of protected structures, it was found that naturally ventilated polyhouses named as "rain shelters" are ideal for the humid tropical climatic conditions of Kerala. With the tropicalisation of cool season vegetables scope of cultivating them in non traditional areas like plains of Kerala is increasing, due to its high demand and lucrative price.

The present study entitled "Performance analysis of tropical cabbage (*Brassica oleracea* var *capitata* L.) hybrids under open and protected conditions" was attempted to identify an ideal hybrid of tropical cabbage for plains and also to study the feasibility of cabbage cultivation in protected and open field conditions during on and off- seasons.

Results of the study are discussed under the following heads.

5.1. Influence of growing condition on vegetative characters

5.2. Influence of growing condition on growth and maturity

5.3. Influence of growing condition on yield and yield attributes

5.4. Influence of growing condition on pest and diseases

5.5. Crop weather correlation

5.6. Economics of cultivation

5.1. INFLUENCE OF GROWING CONDITION ON VEGETATIVE CHARACTERS

5.1.1. Early plant vigour:

Plug tray seedlings of all hybrids exhibited good early plant vigour in both seasons. This may be due to the better growing condition provided to individual seedlings in the plug tray. According to Singh *et al.* (2007) technique of raising seedlings in plug tray is capable of producing vigorous root development, suitable for nursery raising without any damage to seedlings and for off- season raising of seedlings. Higher rates of seed germination, less pest and disease incidence, uniformity of seedlings with no transplanting shock and easy handling and economy in transportation are the other advantages of this method.

5.1.2. Leaf colour:

Colour variation in leaves was noticed in the crops when grown under different growing conditions during off- season. Rain shelter crop showed blue green colour while open field crop showed green colour during off- season. During on- season both rain shelter and open field crop showed blue green leaf colour. The colour difference in leaf may be due to the influence of high rainfall in the open field, and exposed to more light.

5.1.3. Number of non wrapping leaves:

In cabbage, higher number of non wrapping leaves is considered as an undesirable trait (Agarwal *et al.*, 1972). During off- season, lowest number of non wrapping leaves was observed inside the rain shelter for the hybrid NS 43 (7.40) and it was higher in the open field in the hybrid Disha (14.95) while in the on- season lowest number of non wrapping leaves was observed in NS 43 and highest in NS 183 (16.08). During on- season also, higher number of non wrapping leaves was observed in open field conditions.

Chaubey *et al*. (2006) reported that most of the early maturing genotypes showed lower number and late maturing showed higher number of non wrapping leaves. In the present study also NS 43 was found to early maturing. He also reported that unfavourable climatic conditions during the growth period results in the formation of more number of non wrapping leaves and thus more energy is diverted to the production of these leaves. Thus rainfall received by the off- season crop can be a factor which led to the production of more number of non wrapping leaves under open field condition.

5.1.4. Number of wrapping leaves:

The number of wrapping leaves was less than the number of non wrapping leaves in all the hybrids during off- season inside the rain shelter. In the on- season, there was no significant difference between the number of wrapping leaves with respect to growing conditions.

5.1.5. Plant spread:

Plant spread was found to be more during on- season when compared to the off- season. During off- season, it was more for the rain shelter crop and the hybrid NS 43 recorded maximum plant spread (48.20cm). During on- season, NS 35 (65.41cm) showed maximum plant spread inside the rain shelter and open field (67.66cm). Similar results were reported by Suseela (2002) in cauliflower when grown in two seasons. She also reported that the yield was found to increase with increase in plant spread upto 82cm and thereafter a substantial reduction in yield was observed. In the present study also it was noticed that maximum yield during on- season was noticed for the hybrid NS 35 which was having a plant spread of 65.41cm inside rain shelter and 67.66cm in open field.

According to Chaubey *et al*. (2006) maximum plant spread was noticed with highest fertility levels in both seasons and usually smaller plant spread is preferred because it allows greater plant population per unit area.

Suseela (2002) also noticed that under normal conditions, the yield of the plant will increase with increase in plant spread. But in the case of the first crop (off- season),

some of the plants showed abnormal vegetative growth and produced smaller sized curds, due to high temperature.

The low plant spread in the open field crop during off- season might be due to the small leaf size and it can be explained with the unfavourable weather parameters present during that time. Chaubey *et al*. (2006) also reported that higher value of leaf shape index showed maximum plant spread while lower value showed minimum plant spread. Thus it can be concluded that plant spread is having a relationship with the leaf size. Srihari and Satyanarayan (1992) also reported that the leaf size had direct bearing on plant spread.

In a correlation study conducted by Singh *et al*. (2010) it was reported that frame spread had significant positive correlation with gross plant weight, equatorial diameter, polar diameter, net head weight and core length; whereas negative correlation with head compactness and head shape index. They also reported that significant positive correlation of frame spread will result in accommodating a lesser number of plants per unit area. But an optimum plant spread is required for obtaining maximum yield. Very low plant spread will result in very low net weight and yield.

5.1.6. Stalk length:

Stalk length was minimum for the rain shelter crop during off- season and it was least for the hybrid NS 43 (6.99cm). In open field it was minimum for NS 35 (7.41cm). But in on-season stalk length was lower for the same hybrid. Stalk length within this range was observed by Rana and Singh (2010) in some other cultivars. According to Pradeepkumar *et al*. (2002) early planting induced production of short stalks and interaction between varieties and planting date were observed to be significant for the character, stalk length.

5.2. INFLUENCE OF GROWING CONDITION ON GROWTH AND MATURITY

5.2.1. Days to 50% head formation:

During off- season, inside the rain shelter the hybrid NS 43 was the earliest to form fifty percent heads (52.00) and the hybrids failed to form heads in the open field. Only one or two miniature heads were formed in each replication in the open field during rainy season while during on- season, NS 43 was early in open field (49.25) than in rain shelter (50.00). During both seasons NS 35 was the late to form fifty percent heads inside and outside the rain shelter.

Suseela (2002) reported that there was significant difference in the days to curd initiation in cauliflower between the different growing conditions. In the open field, initiation of curd occured very late compared to the green house. The days to curd initiation of the plants in the open field were significantly higher than that of all the three greenhouses. Contradictory to this result, in the present study fifty percent heads in cabbage were formed very early in open field during on- season. Variability in time of curd initiation appeared to be mainly a function of time on which the juvenile phase ended (Booji, 1990.)

According to Tanaka and Niikura (2003) early maturing F1 hybrid cultivars had the following developmental characteristics: change to large leaf shape index from the low leaf position, low leaf position at which their head formation started and large leaf size. Thus leaf size and plant spread had a relationship between earliness to fifty percent head formation. From the table 4.5 and table 4.7 it is clear that NS 43 was the earliest and obtained maximum plant spread during off- season. They also suggested that earliness of head formation was highly correlated with the leaf position at which head formation (LPH) started i.e. lower the LPH value, earlier the head formation. However, the LPH value in some cultivars varied with the growing season, showing a significant genotype (G) x environment (E) interaction. Thus it can be concluded that seasons or weather conditions also have an influence on days to fifty percent head formation.

5.2.2. Days to 50% head maturity:

NS 43 attained early maturity during both seasons inside the rain shelter while NS 183 was early to mature in open field during on- season (71.75). During on- season, the open field crop was early than the rain shelter crop. Disha was late to mature during off- season and NS 35 was late to mature during on- season under both growing conditions. Sherma and Verma (2000) also got similar results in the number of days taken by the crop to achieve fifty percent maturity in some other varieties.

The early maturing cultivars produce lower yields due to a shorter growing season while the late maturing gives higher yields (Lal, 1993). Similar results were obtained in the present study also.

Chaubey et al. (2006) noticed early maturity in spring summer (off- season) planting as compared to winter spring planting and they explained that the reason for the early maturity could be the prevailing high temperature, which forced the crop to complete the vegetative growth and heading early. But in the present study rainy season was taken as off- season and during that period, humidity was higher when compared to the on- season and it was observed that on- season crop was earlier to attain maturity than the off- season crop.

Increases in head weight, size and density were relatively rapid after initiation but slowed as heads reached horticultural maturity (de Moel and Evaraats, 1990). According to Howe and Waters (1994) the influence of abiotic growth factors on crop maturity appears to vary with genetics. Thus the genotypic character of the hybrids also has an influence on the number of days to attain fifty percent head maturity.

Pradeepkumar *et al.* (2002) noticed highly significant interaction between varieties and dates of planting which indicates the critical influence of environment on genotypes in inducing the earliness in cauliflower. According to Strandberg (1979) head diameter, weight and firmness increase and moisture content may decrease during head formation and maturation.

5.3. INFLUENCE OF GROWING CONDITION ON YIELD AND YIELD ATTRIBUTES:

5.3.1. Gross head weight:

Maximum gross weight was observed for the hybrid NS 183 (986.75g) inside the rain shelter during off- season. During on- season, Disha recorded maximum gross weight (1655g) inside the rain shelter and under open condition, maximum gross weight was observed for NS 35 (2401.00g). Mean gross weight for the open field was higher than the protected crop during on- season.

From the table 4.8 and table 4.10 it is evident that NS 35 was the higher yielder and also the late to mature. Similar results were reported by Damato *et al*. (1996). They reported that late maturing accessions consistently averaged greater high yield.

Suseela (2002) noticed that the plant exhibited maximum vegetative growth during the initiation of curd and declined thereafter toward harvest. Hence vegetative parameters at this stage were related to the yield of the plant. Plant spread beyond 82cm resulted in reduction of yield and also indicated that over vegetation caused delayed curd formation and reduced yield.

Pradeepkumar *et al*.(2002) noticed that early planting produced largest net and gross weight and total yield. The cultivars PES-1, F1- 598, PES- 3 and Pusa Sharad produced largest curds and were on par. Isenberg *et al*. (1975) recorded increase in weight and density over a 20-30 day period beginning approximately 100 days after planting and found that the changes were cultivar dependent.

Gross weight is having negative correlation with head compactness and a positive correlation with plant spread (Singh *et al*., 2010). Higher yield of NS 35 during on- season can be attributed to this.

5.3.2. Net head weight:

During off- season, maximum head weight was observed in the hybrid NS 43 (553.50g) followed by NS 183 (545.75g) and in on- season NS 35 recorded

maximum head weight under both growing conditions with 1725g under open condition and 1131g inside rain shelter. Mean head weight in open field was more than that of the rain shelter crop.

According to Posta and Berar (2006) head weight is closely associated with head efficiency and head volume. Plant spacing also has an influence on net head weight (Khatiwada, 2001).

Theodore *et al.* (2004) noticed that air temperatures also influence the terminal size and weight of mature heads and changes in head size and head weight correlate strongly with thermal time. Thus the temperature difference during the two seasons can be the cause of difference in net weight during the two seasons.

The negative correlation of head shape index with net head weight implies that flat or drum head type plants or genotypes would produce cabbage heads with higher net weight (Singh *et al.*, 2010).

5.3.3. Harvest index:

Harvest index was found to be more for the on- season crop than the off- season crop. This might be due to the favourable conditions available during the on- season which resulted in higher biomass production. Harvest index was found to be maximum for NS 43 (67.70) during off- season while in on- season it was maximum for NS 35 under protected (70.75) and open conditions (72.00). Similar results were reported in broccoli also (Sharma *et al.*, 2000).

Harvest index is a yield attribute which can lead to high yield and it is found to have a direct relationship with yield (Sharma *et al.*, 2006). The present result is in line with this study. In present study, maximum harvest index and net head weight was obtained for the hybrid NS 43 during off- season inside rain shelter and for NS 35 during on- season under both growing conditions.

5.3.4. Total number of marketable heads:

Eventhough there was no significant difference between the hybrids in this character, maximum number of marketable heads was observed for the hybrid NS 43 during off- season and on- season under protected conditions and NS 35 and Disha formed maximum number of marketable heads during on- season under open field condition.

5.3.5. Head shape:

Head shape of all the hybrids except NS 43 was found to be conical during off- season under rain shelter. NS 43 formed drum head shaped heads under rain shelter. Head formation was not observed in NS 35 during off- season in open field and only one or two miniature heads were formed in open field in other hybrids. During on- season, NS 183, NS 35 and Disha formed round shaped heads under both growing conditions while NS 43 formed drum head shaped heads.

Sundstrom and Story (1984) suggested that temperature had significant effect on cabbage head shape. Similar results were reported by Isenberg *et al*. (1975); Nillson (1988); and Stanberg (1979). Kleinhenz and Wszalaki (2003) suggested that head traits like head shape is a result of cumulative environmental conditions and that conditions early on the plant and crop development may have a stronger influence on these traits. All these results show that environmental conditions during the crop period had an influence on the head shape.

Kelbert (1959) reported malformations like pointed heads when the plants were exposed to very low temperature and the affected heads did not develop firmness. Suseela (2002) reported malformations such as abnormal vegetative growth with smaller sized curds in cauliflower when exposed to high temperature. This also suggests that optimum temperature has an important role in the head shape.

The green round headed types are most preferred by the consumers (Splittstoesser, 1979; Philips and Ris, 1993). Head shape was observed to flatten during development. Since optimal head shape for most markets is represented by a polar: equatorial diameter ratio of 1.0 (round), changes in head shape during development may affect the relative marketability of heads harvested at different maturities.

The negative correlation of head shape index with net head weight implies that flat or drum head type plants or genotypes would produce cabbage heads with higher net weight (Singh *et al*., 2010).

5.3.6. Head compactness:

During off- season, NS 183 formed medium compact to compact heads under protected condition. NS 43 formed compact heads inside rain shelter. For the hybrid NS 35, heads were not formed under open field and the heads formed inside rain shelter were medium compact to compact. Disha formed compact heads in rain shelter.

In on- season, the hybrids NS 183 and NS 43 formed very compact heads under both growing conditions. Hybrid NS 35 formed compact heads under protected condition and very compact heads in open field while Disha formed very compact heads under rain shelter and compact heads in open condition.

Khatiwada (2001) reported that increasing the plant population decreased the compactness up to a level. Singh *et al*. (2010) reported that head compactness is having a negative correlation with gross weight and plant spread. Ram (1997) reported that net weight of the head (without stalk and non wrapper leaves) also gives a fair idea about the compactness. More the weight, higher the compactness. In the present study, during on- season NS 35 was having maximum weight under both growing conditions and very compact also.

5.3.7. Head length, breadth and head index:

During on- season, Disha recorded maximum head length inside the rain shelter (16.25cm) and it was on par with NS 183 (15.91cm) and NS 35 (15.54cm). Under open conditions, NS 35 recorded maximum head length of 16.91cm and it was on par

with Disha (15.29cm). The mean head length inside the rain shelter was 15.59cm and that of outside crop was 15.13cm respectively.

During off- season, inside rain shelter maximum value for head breadth was recorded for the hybrid NS 43 (14.05cm). Maximum head breadth during on- season crop was observed for the hybrid NS 35 under open condition (17.66cm) and inside the rain shelter it was highest for NS 43 (15.45cm).

According to North (1957) there is a relationship between head diameter and weight and Kleinhenz and Wszalaki (2003) reported that head expansion was greatest in the equatorial direction as indicated by a decrease in the ratio of polar: equatorial diameter (head index) during development. They also noticed that head growth occur primarily perpendicular to the core which results in a change in head shape.

Ram (1997) reported that shape of the head is usually expressed in terms of polar and equatorial diameters and these ratios are spherical head- 0.8 to 1.0, drum head- 0.6 or less, conical head- more than 1.0.

During off- season, NS 183 recorded a head index of 1.34. NS 43 was having a head index value of 0.92 and NS 35 with 1.12. Disha showed a head index of 1.48 inside the rain shelter. During on- season, inside the rain shelter NS 183 recorded a head index of 1.09 and 1.03 under open filed condition. For NS 43, it was 0.95 inside rain shelter and 0.82 under open field. NS 35 had shown a value of 1.02 inside rain shelter and 0.95 under rain shelter and for Disha the value was 1.11 inside rain shelter and 1.03 under open field condition.

The negative correlation of head shape index with net head weight implied that flat or drum head type plants or genotypes would produce cabbage heads with higher net head weight which otherwise was not desirable from the view point of consumers and maturity (Singh *et al.*, 2010).

5.3.8. Core length:

During off- season, inside the rain shelter minimum core length was observed for NS 43 (6.92cm) and it was on par with NS 35 (7.52cm) and Disha (8.28cm). Core length

inside the rain shelter during on- season was minimum for NS 43 (7.87cm) and it was on par with NS 183 (8.79cm) and NS 35 (7.87cm). Under open conditions also NS 43 was having minimum core length of 6.91cm and it was on par with NS 35 (7.35cm). Mean core length of outside crop was found to be lower than that of rain shelter crop during on- season.

Generally a short core less than 25 percent of head diameter is preferred. Kleinhenz and Wszalaki (2003) noticed that relationship between head and core volume is a key indicator of crop quality, since the core is removed prior to fresh market consumption or processing. As heads develop a decrease in percentage head volume occupied by the core results in more usable product available to processors and consumers.

5.5. INFLUENCE OF GROWING CONDITIONS ON PEST AND DISEASES:

5.5.1. Pest incidence:

Tobacco caterpillar (*Spodoptera litura*) was the major pest found during both seasons. Pest incidence was more in open field during off and on seasons. But when compared to off-season, it was more during on season i.e. from October- January. Similar results were reported by Varalakshmi *et al* (2006). They reported that the months of December and January were favourable for the multiplication of *S. litura*.

Among the hybrids lowest pest incidence was noticed in NS 35 (2.5%) under protected conditions and Disha (9.47%) under open field conditions during off- season. During on-season it was lowest for NS 43 and NS 35 (17.5%) inside rain shelter and in open field it was higher than in rain shelter for all the hybrids. However in NS 35 (30%) it was slightly lower when compared to other hybrids. Patait *et al* (2008) reported that increased number of rainy days and decreased rainfall increased the population of *S. litura* on cabbage during rainy season with its peak in 40th meteorological week, while increased forenoon relative humidity and decreased afternoon relative humidity increased its population on cabbage during winter season.

Besides this, leaf webber (*Crocidolomia binotalis*) and painted bug (*Bagrada hilaris*) were also noticed during on- season. Varalakshmi *et al* (2006) *and* Patait *et al* (2008) also noticed the incidence of these pests in cabbage.

5.5.2 Disease incidence:

Damping off was noticed for all the treatments during nursery stage. It is caused by species of *Pythium*. High soil moisture and temperature favour the rapid development of this disease (Dohroo, 2001.)

Disease incidence was very high in open field conditions during off- season. Head rot caused by *Alternaria brassicae* was noticed. Kolte (1985) reported that yield losses to an extent of 10- 70% have reported in different *Brassica sp* from different countries due to this disease.

During off- season, disease incidence was more under open field conditions and from the percentage incidence worked out it was observed that Disha recorded highest (49.7%) incidence followed by NS 35 (48.06%). It was minimum for NS 43 (38.81%). Inside the rain shelter minimum incidence was observed in NS 183 (2.5%) followed by Disha (15%), NS 43 (17.5%) and maximum in NS 35 (25%).

During on- season, no major disease incidence was noticed both under rain shelter and in open field. The high disease incidence during off- season in open field may be due to the high humidity prevailing at that time.

5.6. CROP WEATHER CORRELATION:

As the days to 50 percent head formation was positively correlated with maximum temperature during off- season, increase in temperature during this time will affect the crop adversely. Delay in head formation will occur because of this. Similar results were reported by Wien and Wurr (1997). According to Nowbuth and Pearson (1998) production of leaves in cauliflower was affected by temperature.

Relative humidity at morning showed positive correlation with days to fifty percent head formation inside rain shelter during off- season and days to fifty percent head maturity inside rain shelter during on- season. Hence, increase in the RH (morning) can delay the head formation and head maturity. Gericke (2007) also reported similar results. He also reported that too much water causes the head to burst and too humid conditions around the base of the plant stimulate leaf rot.

From the table 4.17 it is clear that an increase in the relative humidity at noon decreased the number of days to head formation and head maturity inside the rain shelter during on and off- seasons. It also had a positive effect on the yield per harvest during off- season.

Minimum temperature showed negative correlation with days to fifty percent head formation, yield per harvest during off- season while days to fifty percent maturity were negatively correlated. So an increase in minimum temperature will decrease the days to fifty percent head formation and increase the days to fifty percent maturity and yield per harvest.

From the table 4.18 and 4.19 it is evident that during the time of fifty percent head formation inside the rain shelter i.e. in the 43rd and 44th standard weeks, the open field crop received a rainfall of 13.4mm and 22mm respectively and the relative humidity was also very high. These may have adversely affected the open field crop and prevented it from head formation during off- season.

Tables 4.20 and 4.21 shows that the relative humidity values obtained from the rain shelter during off- season was in range with those of the on- season crop thus providing the rain shelter crop with favourable conditions for head formation during off- season.

5.7. ECONOMICS OF CULTIVATION:

During off- season inside the rain shelter, the total cost for cultivation (including the construction cost and interest on fixed capital) was recorded as Rs. 48.30 per m^2 and the total benefit was Rs.55.12 per m^2. Benefit –cost ratio of the rain shelter crop

during the off- season was 1.14. In the open field, as none of the plants formed marketable heads benefit- cost ratio could not be calculated.

During on- season, the total cost for cultivation (including construction cost and interest on fixed capital) was recorded as Rs. 47.90 per m^2 and the total benefit was Rs. 49.00 per m^2 inside the rain shelter. B: C ratio calculated was 1.02 inside the rain shelter. Under open field conditions, the total cost of cultivation was Rs.23.00 per m^2 and the total benefit was Rs.61.18 per m^2 and B: C ratio was 2.66.

Suseela (2002) reported a B: C ratio of 1.168 for cauliflower cultivation in open field while it was 2.28 for a 3.75m greenhouse. She reported that costs of weeding and plant protection measures were more in open field thus decreasing the B: C ratio in open field.

B: C ratio was more in the open field during on season when compared to rain shelter crop. The yield was lesser inside the rain shelter. This may be due to the higher temperature inside the rain shelter during the head formation stage when compared to open field. This can be overcome by early planting inside the rain shelter. If we are planting by the month of August an early crop of cabbage can be harvested by October from the rain shelter so that the farmer will get a higher price for his produce also.

Though the B: C ratio was 1.14 inside the rain shelter during off- season, when compared to open field it is very remunerative. If we are utilising family labour, benefit will be more. Thus there is much scope for self employment for the unemployed youth of Kerala by utilising this protected cultivation as an agri business.

Summary

6. SUMMARY

An investigation was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-2011with the objective to study the performance of F1 hybrids of cabbage (*Brassica oleracea* var *capitata* L.) under protected and open conditions.

The experiment was laid out in a Randamized Block Design with four replications. Four hybrids viz, NS 183, NS 43, NS 35 and Disha were used for the study. Observations on growth and yield attributes were recorded during the course of investigation. The daily weather parameters recorded inside and outside the polyhouse were used to compute the crop weather relationship. The salient results obtained during the course of investigation are summarized below.

- Non wrapping leaves were less inside polyhouse during both seasons
- During off- season, plant spread was found to be more inside the rain shelter than in the open field. Maximum plant spread was observed inside the rain shelter for the hybrid NS 43 (48.20cm) which was on par with the other varieties
- It was observed that during on- season, inside the rain shelter plant spread was more in NS 35 (65.41cm) which was on par with NS 43 (61.91cm). NS 35 was found to be having the maximum plant spread in open field (67.66cm) followed by NS 43 (59.25cm).
- NS 43 was the earliest to achieve 50% head formation (during both seasons and growing conditions) and to achieve 50% maturity (during both seasons inside polyhouse)
- During on- season, NS 183 achieved early maturity in open field
- Net head weight was maximum for NS 43 inside polyhouse during off- season and for NS 35 inside and outside polyhouse during on- season

- Head shape of all the hybrids except NS 43 was found to be conical during off- season inside rain shelter. NS 43 formed drum head shaped heads under rain shelter
- NS 183, NS 35 and Disha formed round shaped heads while NS 43 formed drum head shaped heads during on- season under both growing conditions.
- During off- season, inside the rain shelter maximum head length was observed for the hybrid Disha (14.26cm) and it was on par with NS 183 (13.93cm)
- Disha recorded maximum head length inside the rain shelter during on- season also (16.25cm) and it was on par with NS 183 (15.91cm) and NS 35 (15.54cm)
- Core length inside the rain shelter during on- season was minimum for NS 43 (7.87cm) and it was on par with NS 183 (8.79cm) and NS 35 (7.87cm)
- During off- season, inside the rain shelter harvest index was found to be maximum for NS 43 (67.70) which was on par with NS 183 (60.46)
- Pest and disease incidence was more in open field crop during both seasons
- Crop weather correlation(Off- season):

✓ Inside the rain shelter, days to fifty percent head formation was positively correlated with maximum temperature and relative humidity at morning while it showed negative correlation with minimum temperature and relative humidity at noon.

✓ Days to fifty percent head maturity is positively correlated with minimum temperature and negatively correlated with relative humidity at noon

✓ Yield per harvest showed negative correlation with minimum temperature while it was positively influenced by relative humidity at noon.

- Crop weather correlation (On- season):

✓ Inside the rain shelter, days to fifty percent head formation showed significant correlation with all the weather parameters recorded.

✓ It was positively correlated with minimum temperature and relative humidity at noon while negatively affected by the maximum temperature and relative humidity at morning.

✓ Days to fifty percent head maturity also showed significant positive correlation with minimum temperature and relative humidity (at morning and noon) while it was negatively influenced by maximum temperature.

✓ Under open field conditions, days to fifty percent head formation was negatively correlated with maximum temperature and relative humidity at morning and it showed positive correlation with minimum temperature and relative humidity at noon.

✓ Days to fifty percent head maturity showed positive correlation with max temperature, relative humidity (at noon and morning) while it was negatively correlated with minimum temperature.

✓ Yield per harvest showed no correlation with any of these weather parameters during on-season under both growing conditions.

- Benefit –cost ratio of the rain shelter crop during the off- season was 1.14
- During on- season, B: C ratio calculated was 1.02 inside the rain shelter and under open field conditions, B: C ratio was 2.66.

References

REFERENCES

Agarwal, M.L., Singh, C.N., Bhan, C., and Singh, H.N. 1972. Effect of nitrogen, phosphorus, phosphate and potash on cabbage. In: *Proc. Third Int. Symp. Trop. Subtrop. Hort*. Banglore, Feb.1972. pp142-143.

Amr, A. and Hadidi, N. 2001. Effect of cultivar and harvest date on nitrate (NO_3) and nitrite (NO_2) content of selected vegetables grown under open field and greenhouse conditions in Jordan. *J. Fd. Composition Analysis*.14: 59-67.

Anuja, Joon, M.S. and Ahmed, Z. 2008. Hi-Tech horticulture technology adoption- need of hour in Indian economy. *Green Fmg.*1 (10-11): 78-81.

Apahidean, A.S., Apahidean, M., Maniutiu, D., Ganea, R., Paven, I., and Ficcor, D. 2004. The influence of plant protection on cabbage cultivated on polyethylene film greenhouse. *Notulae Botanicae, Horti Agro Botanici*. 32: 27-29.

Bakker, J.C. 1984. Physiological disorders in cucumber under high humidity conditions and low ventilation rates in greenhouse. *Acta. Hort*. 156: 257-264.

*Bakker, J.C. 1991. Analysis of humidity effects on growth and production of glasshouse fruit vegetables. Ph.D Thesis, Agricultural University Wageningen, Netherlands, 185p.

Batal, K.M., Granberry, D.M., and Mullinix, B.G. 1997. Nitrogen, magnesium, and boron applications affect cauliflower yield, curd mass and hollow stem disorder. *Hort. Sci.* 32: 75-78.

Bhagat, I.B., Kumar, R.R., and Kumar, A. 2009. Design, development and evaluation of low cost greenhouse technology to suit cold desert conditions. *Enviro. Ecol.* 27(1A): 465-471.

Bhat, M.A. 2008. A report on insect pests associated with cole crops in Kashmir. *Appl. Biol. Res.* 10: 66-67.

Booji, R. 1990. Effects of juvenility and temperature on time of curd initiation and maturity of cauliflower. *Acta Hort*. 267: 305- 312.

Bot, G.P.A. 2003. The solar greenhouse; Technology for low energy consumption. *Acta. Hort*. 611: 61-69.

Chaubey, T., Srivastava, B.K., Singh, M., Chaubey, P.K., and Rai, M. 2006. Influence of fertility levels and seasons on maturity and morphological traits of cabbage. *Veg. Sci.* 33(1): 29-33.

Chaudari, N., Ghosh, S., Ghosh, J., and Senapati, S.K. 2001. Incidence of insect pests of cabbage in relation to prevailing climatic conditions on Terai region. *Indian J. Ent*. 63(4): 421-428.

Chaudhari, M.L. and Shukla, R.K. 2004. Use of Plasticulture in Horticulture. In: Chadha, K.L., Ahloowaliya, B.S., Prasad, K.V., and Singh, S.K. (eds.), *Crop improvement and production technology of horticultural crops. Vol I.* Proc. of first Indian Hort. Congress, 6- 9 Nov, 2004, New Delhi, pp. 284-294.

Damato, G., Bianco, V.V., and Pomarici, R. 1996. Yield, morphological and phonological characteristics of a collection of cima di rapa (*Brassica rapa* L). *Acta Hort*. 407: 283-291.

de Moel, C.P. and Evaraats, A.P. 1990. Growth, development and yield of white cabbage in relation to time of planting. *Acta Hort*. 267: 279- 296.

Dhamo, K.B. and Jotwani, M.G. 1984. *Insects in Vegetables*. 250p.

Dohroo, N.P. 2001. Diseases of cole crops and their control. In: *Vegetable production advances*, Dept. Of Veg crops, Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh,pp.128-129.

Donnan, R. 1993. Water and nutrient management. In: *Commercial Hydroponics in Australia*. Australian hydroponic Association Inc. pp. 76-104.

DuhSukh, H. 1999. Quality improvement of Chinese cabbage using rain shelter and fertigation system in summer production. *Acta. Hort*. 483: 199-207.

Farnham, M.W., Wilson, P.E., Stephenson, K.K. and Fahey, J.W. 2004. Genetic and environmental effects on glucosinolate content and chemoprtotective potency of broccoli. *Plnt. Breeding* 123: 60-65.

Freed, R. 1986. *MSTATC Version 1.2*. Department of crop and soil science, Michigan State university, p97.

Friend, D.J.C. and Helson, V.A. 1976. Thermoperiodic effect on the growth and photosynthesis of wheat and other crop plants. *Bot. Gaz*. 137: 75-84.

Friend, D.J.C. 1985. Brassica. In: Halevy, A.H. (ed). *CRC Handbook of flowering.vol 2*. CRC Press, Boca Raton, Florid pp. 47-77.

Gowade, M.H., Patil, J.D., and Kakade, D.S. 2004. Studies on effect of intercrops on yield and monetary returns of cabbage. *Agric. Sci. Digest* 24(1): 23-26.

Gericke, W.F. 2007. *Soilless Gardening: A Complete Guide*. Biotech Books, Delhi, 334p.

Golizadeh, A., Kamali, K., Fathipous, Y., and Abbasipour, H. 2004. Effect of temperature on life table parameters of *Plutella xylostella* (Lepidoptera: Plutellidae) on two Brassicaceous Host Plants. *J. Asia. Pacif. Ent*. 12: 207-212.

Gopalakrishnan, T.R. (ed). 2004. *Three Decades of Vegetable Research in Kerala Agricultural University*. Kerala Agricultural University, Thrissur, 130p.

Hansen. M., Benglsson, G.B., and Borge, G.I. 2010. Red Cabbage, A vegetable rich in health related glucosinolates. *Acta Hort*. 867: 61-63.

Hernandez, J., Soriana, T., Morales, M.I., and Castilla, N. 2004. Row covers for quality improvement of Chinese cabbage (*Brassica rapa* subsp *pekinensis*). *Newzealand J. Crop Hort. Sci*. 32(4): 379- 388.

Horiuchi, S. and Hori, M. 1980. A simple greenhouse technique for obtaining high levels of clubroot incidence. *Bull. Chugoku Natl. Agric. Exp. Stn*. 17: 33-35.

Howe, T.K. and Waters, W.E. 1994. Two year summary of cabbage cultivar yield trials. *Prc. Flo. State Hort. Soc*. 107: 95- 99.

Huxsoll, C., Bolin, H., and King, A. 1989. *Quality factors of Fruits and Vegetables- Chemistry and Technology*. American Chemical Society, Washington.D.C.

*Ilias, M.K. and Ramli, M.N. 1994. Pengeluaran Sayuran Brassica di Bawah Struktur Pelindung Hujan. *Teknologi Sayur Sayuran Jil*. 10: 7-12.

Isenberg, F.M.R., Pendergrass, A., Carroll, J.E., Howell, L., and Oyer, E.B. 1975. The use of weight, density, heat units, and solar radiation to predict the maturity of cabbage for storage. *J. Am. Soc. Hort. Sci*. 100: 313- 316.

Kachru, R.P. 1985. Greenhouse Temperature control techniques. In: *Handout Delivered during Summer Training on Greenhouse Design and Environmental Control*, Central Institute of Agricultural Engineering, Bhopal, India, pp.G36-G46.

Kalia, P. 1995. Biochemical assays and yield performance of sprouting broccoli genotypes of Himachal Pradesh. *Crucifera Newsl.* 17: 90-91.

Kamaruddin, R. 2007. Design and development of naturally ventilated tropical crop protection structures and hydroponics systems. *Acta. Hort*. 742: 139-154.

Kanwar, H.S. 2001. Advances in production of Cabbage (*Brassica oleraecea* var *capitata*). In: *Advances in Vegetable production*, Centre for advanced studies in Horticulture(Veg), Department of Veg crops Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, pp.121-123.

KAU [Kerala Agricultural University]. 1999. *Report of XVII Zonal Research and Extension Advisory Council Meeting, 11 March, 1999*. Regional Agricultural Research Station, Ambalavayal, Wayanad, 68p.

KAU [Kerala Agricultural University]. 2001. *Report of XVIIIst Zonal Research and Extension Advisory Council Meeting, 14 September,2001*. Regional Agricultural Research Station, Ambalavayal, Wayanad, 20p.

KAU [Kerala Agricultural University]. 2007. *Package of Practice Recommendations: Crops*. Directorate of Extension, Kerala Agricultural University, Thrissur, 334p.

KAU [Kerala Agricultural University]. 2009. *Report of XXXIst Zonal Research and Extension Advisory Committee Meeting, 30 May 2009*. Regional Agricultural Research Station, Mele Pattambi, 25p.

Kelbert, D.G.A. 1959. *Head Formation of Cabbage as Affected by Exposure to Low Temperature*. Florida State Horticulture Society, 215p.

Khan, S.H., Ahmed, S., Murtaza, I., Jabeen, N., and Chatoo, M.A. 2006. Mean performance of some kale (*Brassica oleracea* var *acephala* L.) genotypes for various quality attributes. *S. Indian Hort*. 54(1-6): 177-180.

Khatiwada, P.P. 2001. Plant Spacing: A key husbandry practice for rainy season cabbage production. *Nepal Agric. Res. J*. 5: 48-55.

Kleinhenz, M.D. and Wszelaki, A. 2003. Yield and relationship among head traits in cabbage as influenced by planting date and cultivar. *Hort Sci.* 38(7): 1349-1354.

Kolte, S.J. 1985. *Diseases of Annual Oilseed Crops Vol II. Rapeseed-Mustard and Sesame Diseases*. CRC, Boca Raton, Florida, 135p.

Kopsell, D.A., Kopsell, D.E., and Lefsrud, M.G. 2004. Variation in lutein, β-carotene and chlorophyll concentrations among leafy *Brassica oleracea* cultigens. *Hort. Sci.* 39(2): 361-365.

Kumar, A. 2006. Plastics in Agriculture. In: Chadha, K.L. and Swaminathan, M.S. (eds.), *Environment and Agriculture*, Malhotra Publishing House, NewDelhi. pp.334-350.

Kumar, P.R., Yadav, S.K., Sharma, S.R., Lal, S.K., and Jha, D.N. 2009. Impact of climate change on seed production of cabbage in northern and western Himalayas. *Wld. J. Agric. Sci.* 5(1): 18-26.

Kuo, C.G., Shen, B.J., Chen, H.M., Chen, H.C. and Opena, R.T. 2002. Associations between heat tolerance, water consumption and morphological characters in Chinese cabbage. *J. Agric. Food Chem*. 50(7): 1964-1969.

Lal, G. 1993. *Advances in Horticulture*. Malhotra Publishing House, New Delhi, 508p.

Mahajan, R.K., Sapra, R.L., Srivastava, U., Singh, M., and Sharma. G.D. 2000. *Minimal Descriptors (for characterization and evaluation) of Agri-Horticulture crops (Parts- II).* National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi, 354p.

Mahajan, V. 2006. Use of polythene for raising vegetable nursery during rains: A low input technology. *S. Indian Hort*. 55(1-6): 47-52.

Mehta, N.A., Sharma, N., Dixit, H.G., and Dubey, P. 2003. Cultivation of Cole crops under protected environment. *Karnataka J. Agric. Sci.* 16(2): 332-334.

Mourao, I.M.G., and Hadley, P. 1998. Environmental control of plant growth development and yield in broccoli (*Brassica oleracea* L.var *italica*): Crop response to light regime. *Acta Hort*. 459: 71-78.

Nilsson, T. 1988. Growth and carbohydrate composition of winter white cabbage intented for long term storage. II. Effects of solar radiation, temperature, and degree days. *J. Hort. Sci*. 63: 431- 441.

Nishijima, T., and Fukuda, N. 2006. Autonomous development of erect leaves independent of light irradiation during the early stage of head formation in Chinese cabbage (*Brassica rapa* L. var.*pekinensis* Rupr). *J. Japan. Soc. Hort. Sci.* 75(1): 59-65.

North, C. 1957. Studies in morphogenesis of *Brassica oleracea* L. growth and development of cabbage during the vegetative phase. *J. Exp. Botany* (18): 304-312.

Nowbuth, R.D. and Pearson, S. 1998. The effect of temperature and shade on curd initiation in temperate and tropical cauliflower. *Acta Hort*. 12(4): 79-87.

Nowbuth, R.D. 1997. Effect of temperature on curd initiation in cauliflower. In: *Proceedings of Second Annual meeting of Agricultural Scientists*, The Food and Agricultural Research council, Mauritius,12-13 Aug 1997, pp. 225-231.

Odour, G.I., Lohr, B., and Seif, A.A. 1996. Seasonality of major cabbage pests and incidence of their natural enemies in Central Kenya. In: *Proceedings: The Management of Diamond Back Moth and other Crucifer pests*, National Agricultural Research Centre, Muguga, Nairobi, Kenya, pp. 38-41.

Patait, D.D., Shetgar, S.S., Subhan, S., Badjugar, A.G., and Dhurgude, S.S. 2008. Seasonal abundance of lepidopteron pests infesting cabbage in relation to weather parameters. *Indian J. Ento*. 70(3): 255-258.

Pearson, A.R. 1979. Quality studies in cauliflower. *Acta Hort*. 93: 443-445.

Philips, R. and Rix, M. 1993. *Vegetables*. Random House, Inc. New York, USA, 243p.

Posta, G.H. and Berar, V. 2006. Researches concerning the yield performances of the early cabbage hybrids cultivated in the field conditions. *Bull.USAMV-CN*(63): 1454-1461.

Prabhakar, M. and Hebbar, S.S. 2006. Peri- urban vegetable production. In: *Chadha, K.L. and Swaminathan, M.S. (eds). Environment and Agriculture*, Malhotra Publishing House, New Delhi, India. Pp. 388-411.

Pradeepkumar, T. and George, T.E. 2009. Cabbage and cauliflower, now not foreigners. *Kerala calling*. 29: 32-33.

Pradeepkumar, T., Babu, S.K., and Aipe, K.C. 2002. Adaptability of cauliflower genotypes in the high ranges of Kerala. *J. Trop. Agric*. 40: 45-47.

Prasad, T.G. 1997. Environment and Plant growth relations in Greenhouse. In: *Proceedings of International Seminar on Protected cultivation in India*, Banglore, India. pp.51-54.

Ram, H.H. 1997. *Vegetable Breeding: Principles and practices*. Kalyani Publishers, New Delhi, 514p.

Rana, D.K. and Singh. N.S. 2010. Performance of some cultivars of cabbage (*Brassica oleracea* L.) under valley conditions of Garhwal Himalaya. *Green Fmg*.3 (2): 139-140.

Rana, M.K. 2008. *Olericulture in India*, Kalyani publishers, New Delhi, 551p.

Ranawana, S.R., Weerakkody, W.A.P. and Wahundeniya, K.B. 2008. Comparison of growing systems for cauliflower (*Brassica oleracea* var *Botrytis*) under tropical greenhouse conditions. *Veg. Sci*. 35(2): 119-123.

Ranghaswami, M.V., Suseela, P., Palaniswamy, D., Ganga, M., Arunadevi, K., and Nandakumar, N. 2005. Effect of height and ventilation of greenhouse on microclimate under tropical condition and its impact on crop growth. In: *Book of Abstracts, International Conference on Plasticulture and Precision farming*, Nov17-21, New Delhi, India.

*Renewick, J.A.A. 2002. The chemical world of crucivores: Lures, treatments and traps. *Ent. Exp. Et. Appicata* 104: 35-42.

Rubatzsky, V.E. and Yamaguchi, M. 1997. *Cole crops: World Vegetables*. Chapman and Hall, New York, 376p.

Saikia, S., Saikia, A., Kotoky, U., Shadeque, A., and Gogoi, S.1998. Protected cultivation of early cauliflower under LDPE rainshelter. *Ann. Biol. Ludhiana* 14(1): 95-98.

Salter, P.J. 1969. Studies on crop maturity in cauliflower: Relationship between times of curd initiation and curd maturity of plants within a cauliflower crop. *J. Hort. Sci.* 44: 129-140.

Sanwal, S.K., Patel, K.K., and Yadav. D.S. 2005. Vegetable production under protected conditions in NEH region: Problems and prospects. *ENVIS Bull. Himalayan Ecol.* 12(2): 36-43.

Sarfraz, M., Dosdall, L.M., and Keddie, B.A. 2005. Evidence for behavioural resistance by diamond back moth, *Plutella xylostella* (L). *J. Appl. Ent*. 129: 149-157.

Satpathy, S., Kumar, A., Shivalingaswamy, T.M., and Rai, M. 2007. Evaluation of new molecules for diamondback moth management in cabbage. *Indian J. Hort*. 64(2): 175-177.

Satpathy, S., Shivalingaswamy, T.M., Kumar, A., Rai, A.B., and Rai, M. 2010. Potentiality of Chinese cabbage (*Brassica rapa* subsp *pekinensis*) as a trap crop for diamondback moth (*Plutella xylostella*) management in cabbage. *Indian J. Agric. Sci*. 80(3): 238-241.

Schonhof, I., Klaring, H.P., Krumbein, A., Claussen, W., and Schreiner, M. 2007. Effect of temperature increase under low radiation conditions on phytochemicals and ascorbic acid on greenhouse grown broccoli. *Agric., Ecosyst., and Environ*.119(1): 103-111.

*Scopes, N.E.A. 1973. The effects of environment on the development and balance between pests and their natural enemy. *Bull. IOBC/WPRS*. 4: 53-54.

Sharif, M.I. 2006. Design and development of fully controlled environment greenhouse for the production of selected temperate crops in lowland tropics. *Acta Hort*. 710: 127-134.

Sharma, A., Pathania, N.K., Sharma, S., and Pathak, S. 2006. Effect of transplanting time on growth and marketable curd yield of different cultivars of cauliflower (*Brassica oleracea* var *botrytis* subvar *cauliflora*) under dry temperate high hill conditions. *Indian J. Agric. Sci.* 76(6): 343-345.

Sharma, K.C. and Verma, S. 2000. Performance of some cabbage cultivars under dry temperate hills of Himachal Pradesh. *Indian J. Hort*. 57(3): 248-249.

Sharma, P., Sharma, S.R., Sain, S.K., and Dhandapani, A. 2006. Integrated management of major diseases of cauliflower (*Brassica oleracea* var *botrytis* subvar *cauliflora*). *Indian J. Agric. Sci.* 76(12): 726-731.

Sharma, S.R. and Behera, T.K. 2003. Stability of yield and qualitative components in early Indian cauliflower (Group1b). *Indian J.Hort*. 60(3): 268-272.

Sharma, S.R., Behera, T.K., Singh, R., and Chandra, A. 2000. Adaptability in early Indian cauliflower varieties and hybrids (Group IA). *Veg. Sci.* 27(2): 130-132.

*Shinohara, S. 1959. Genecological studies on the phasic development of flowering centering on cruciferous crops, especially on the role of vernalization on ripening seeds. *In: Technical Bulletin No.6 of Shizuoka Prefecture Agric. Exp. Stn. pp.5-64.*

Singhal, P., Srivastava, B.K., Singh, M.P., and Singh, P.K. 2009. Effect of date of planting and spacing on the performance of broccoli. *Indian J. Hort*. 66(1): 137-140.

Singh, B., Kumar, M., Singh, V., and Mehta, S.P. 2007. Plug- tray nursery raising of cucurbits in soil less media: A sustainable technology for off season crop production under northern plains of India. *Acta Hort*. 742: 85- 87.

Singh, B.K., Sharma, S.R., and Singh, B. 2009. Heterosis for mineral elements in single cross-hybrids of cabbage (*Brassica oleracea* var *capitata* L). *Sci. Hort*. 122(1): 3-6.

Singh, B.K., Sharma, S.R., and Singh, B. 2010. Antioxident enzymes in cabbage: Variability and inheritance of superoxide dismutase, peroxide and catalase. *Scientia Hort*. 124(1): 9-13.

Singh, B.K., Sharma, S.R., Kalia, P., and Singh, B. 2010. Character association and path analysis of morphological and economic traits in cabbage (*Brassica oleracea* var *capitata*). *Indian J. Agric. Sci*. 80(2): 116-118.

Splittstoesser, W.E. 1974. *Vegetable Growing Handbook*. The AVI publishing company, Inc. USA, 344p.

Srihari, D. and Satyanarayanan, M. 1992. Evolution of some exotic cabbage cultivars. *S. Indian Hort*. 40(1): 28-33.

Strandberg, J.O. 1979. Growth and phenology of cabbage in a winter production area. *Proc. Flo. State Hort. Soc*. 92: 93-96.

Sundstorm, F.J. and Story, R.N. 1984. Cultivar and growing season effects on cabbage head development and weight loss during storage. *Hort. Sci*. 19: 589- 590.

Suseela, P. 2002. Effect of Height and Ventilation of greenhouse on Microclimate under tropical condition and its Impact on Crop growth. MSc (Ag.Engng.) Thesis, Tamil Nadu Agricultural University, 165p.

Suseela, P. 2008 a. *Design, Construction and Performance Evaluation of Low cost Naturally ventilated Greenhouse suitable for Humid Tropical climate*, K.S.C.T.E, Thiruvananthapuram, 48p.

Suseela, P. 2008 b. Growing cauliflower in greenhouses fetches more. *Indian Fmg*. 58: 9-11.

Tanaka, N. and Niikura, S. 2003. Characterization of early maturing F_1 hybrid varieties in cabbage (*Brassica oleracea* L). *Breed. Sci.* 53: 325-333.

Takegawa, M., Yamato, Y., Hamana, M., Yamazaki, H., and Miura, H. 2004. Growth retardation after transplanting in cabbage (*B.oleracea* L. var *capitata)* and chingensai (*B. campestris* ssp *chinensis*) with root ball shaping of plug seedlings. *J. Japan. Soc. Hort. Sc.* 73(1): 79-81.

Theodore, J.K., Kleinhenz, M.D., and Honeck, N.J. 2004. Important cabbage head traits and their relationship at five points in development. *J. Veg. Crop Prod*. 10(2): 19-32.

Tripathi, R.S. 1999. Ecocnomics of cabbage production in high hills of Uttar Pradesh. *Indian J. Hort*. 56(4): 38-41.

Varalakshmi, P., Rao, P.A., Madhumathi, T., Krishnaiah, P.V., and Rao, V.S. 2006. Occurrence of pest complex in cauliflower. *The Andhra Agric. J*. 53(3&4): 181-183.

Voorips, R.E., Steenhuis-Broers, G., Tiemens-Hulscher, M., and Lammerts Van Bueren, E.T. 2010. Earliness, leaf surfacewax and sugar content predict varietal differences fro thrips damage in cabbage. *Acta Hort*. 867: 127-130.

Wien, H.C. and Wurr, D.C.E. 1997. Cauliflower, broccoli, cabbage, and brussels sprout. In: Wien, H.C. (ed.), *The Physiology of Vegetable Crops*. CAB International, Wallingford, UK, pp. 516-517.

Yau, P.Y., Ahmed, S., Illias, M.K., and Ganisan, K. 2006. Evaluation of cabbage cultivars (*Brassica oleracea* var *capitata*) under plastic rain shelter in mineral soils in the low lands. In*: Proc. IS on greenhouses, Environmental controls & In-house mechanisation for Crop production in the Tropics and Sub tropics, Acta Hort*. 710: 343-346.

Yungwei, S. 1995. The influence of microclimate in structures on cabbage plug seedlings. *Chinese J. Agrometerology* 2(4): 163-168.

*Originals not seen

Appendices

APPENDIX I

Weather data duing off- season (July- Oct 2010) under open field conditions

Standard week	Max temp ^{0}C	Min Temp ^{0}C	RH (Morning) %	RH (Noon) %	Rainfall (mm)
26	30.2	23.1	96	76	28.6
27	28.6	22.8	96	81	26.6
28	31.2	24	95	72	33.2
29	27.8	30	97	84	23.9
30	29.6	22.3	95	81	14.8
31	28.6	22.3	96	74	19.2
32	30.6	24.1	95	73	4.4
33	29.5	23	94	79	6.2
34	28.7	23.3	94	83	1.9
35	28.6	22.8	95	76	9.1
36	29.9	23.1	94	73	5.6
37	29.8	23.2	96	72	21.2
38	30.2	23	95	72	8.1
39	31.9	23	92	68	10.8
40	30.6	22.7	95	78	41.4
41	29.5	23.3	74	70	5.1
42	28.3	21.9	95	78	18.6
43	29.3	27.3	94	76	13.4
44	30.6	22.2	95	71	22
45	30.4	22.3	96	73	17
46	31.3	22.5	92	67	8.5
47	30.8	22.5	91	71	8.7
48	28.1	22.8	83	71	1.2
49	31	21.3	89	59	0.3
50	31.4	21.5	91	59	0.4

APPENDIX II

Weather data during off- season (July- Oct 2010) inside rain shelter

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %
26	32.1	22.8	80	34
27	29.9	21.7	78	36
28	33.4	22.3	76	30
29	30.1	22.5	76	33
30	32.2	22.1	79	29
31	34.3	23.5	81	26
32	32.6	21.5	78	32
33	29.5	21.1	78	33
34	30.2	22.4	82	29
35	30.2	21.9	84	28
36	30	21.4	79	27
37	32.8	21.8	77	24
38	33.5	20.9	76	21
39	34.1	24.1	75	21
40	32.1	20.7	71	36
41	32.8	21.4	37	32
42	29.9	20.1	72	38
43	30.5	25.5	70	35
44	32.4	19.9	73	31
45	31.8	20.2	81	33
46	33.2	19.5	76	29
47	32.6	19.8	75	31
48	29.2	20	61	31
49	33	20.2	64	23
50	32.9	20.4	78	22

APPENDIX III

Weather data during on- season (Oct 2010- Feb 2011) under open field conditions

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %	Rainfall (mm)
40	30.6	22.7	95	78	41.4
41	29.5	23.3	74	70	5.1
42	28.3	21.9	95	78	18.6
43	29.3	27.3	94	76	13.4
44	30.6	22.2	95	71	22
45	30.4	22.3	96	73	17
46	31.3	22.5	92	67	8.5
47	30.8	22.5	91	71	8.7
48	28.1	22.8	83	71	1.2
49	31	21.3	89	59	0.3
50	31.4	21.5	91	59	0.4
51	30.9	22.8	77	55	2.6
52	30.7	21.8	76	51	0
1	31.9	22.3	84	51	0
2	33.2	22.3	89	45	0
3	32.9	20.9	73	36	0
4	32.2	22.9	67	38	0
5	33.4	22.9	61	29	0
6	34.2	21	68	27	0
7	33.9	21.2	75	35	0
8	33.5	22.7	90	52	0
9	33.7	23	73	36	0

APPENDIX IV

Weather data during on- season (Oct 2010- Feb 2011) inside rain shelter

Std week	Max temp ^{0}C	Min Temp ^{0}C	RH (M) %	RH (N) %
40	32.1	20.7	71	36
41	32.8	21.4	37	32
42	29.9	20.1	72	38
43	30.5	25.5	70	35
44	32.4	19.9	73	31
45	31.8	20.2	81	33
46	33.2	19.5	76	29
47	32.6	19.8	75	31
48	29.2	20	61	31
49	33	20.2	64	23
50	32.9	20.4	78	22
51	32	20.8	36	23
52	32.1	19.9	34	21
1	33.1	19.8	62	21
2	34.2	19.9	68	19
3	33.8	19.2	38	18
4	34	20	32	15
5	34.8	20.5	31	16
6	35.5	19.5	31	28
7	35.6	20	38	19
8	34.9	20.3	75	36
9	34.8	20.4	37	35

APPENDIX V

Cost of cultivation of cabbage under rain shelter and open field during off and on seasons ($100m^2$)

Items	Off -season		On-season	
	Rain shelter (Rs.)	Open field (Rs.)	Rain shelter (Rs.)	Open field (Rs.)
A.Labour charges:				
1.Nursery preparation	165	165	165	165
2.Land preparation	225	225	225	225
3. Transplanting	165	165	165	165
4. Earthing up and fertilizer application	165	165	165	165
5. Weeding & top dressing	165	165	165	495
6.Plant protection chemical application	225	225	165	450
7. Harvesting	330	330	330	495
B. Other inputs				
1. Manures & fertilisers	100 50	100 100	100 70	100 300
2. Plant protection chemicals	40	40	40	40
3. Cost of seed				
C. Cost of structure				
1.Construction cost	2000	-	2000	-
2. Interest on fixed capital	1200	-	1200	-
TOTAL COST	4830	1680	4790	2300

PERFORMANCE ANALYSIS OF TROPICAL CABBAGE (*Brassica oleracea* Var *capitata* L.) HYBRIDS UNDER OPEN AND PROTECTED CONDITIONS

By

MALU. K

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF OLERICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2011

ABSTRACT

The present study entitled "Performance analysis of tropical cabbage (*Brassica oleracea* L. var *capitata)* hybrids under open and protected conditions." was undertaken in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010- 2011. The objectives of the study were to identify an ideal hybrid of tropical cabbage for plains and also to study the feasibility of cabbage cultivation in protected and open field conditions during on and off- seasons.

The experiment was laid out in a Randomised Block Design with four replications. Four F1 hybrids namely NS 183, NS 43, NS 35 (Namdhari Seeds Pvt. Ltd.) and Disha (Seminis India Ltd.) were used for the study during off- season (July- Oct) and on- season (Oct- Jan). Protected condition was provided using a rain shelter of 100m^2 floor area. Observations on growth and yield attributes were recorded during the course of investigation. The daily weather parameters recorded inside and outside the polyhouse were used to compute the crop weather relationship

Non wrapping leaves were less inside polyhouse during both seasons. During off- season maximum plant spread was observed inside the rain shelter for the hybrid NS 43 (48.20cm) which was on par with the other varieties and during on- season, inside the rain shelter plant spread was more in NS 35 (65.41cm) which was on par with NS 43 (61.91cm). NS 35 recorded maximum plant spread in open field (67.66cm) followed by NS 43 (59.25cm).

NS 43 was the earliest to achieve 50% head formation during both seasons and growing conditions. It also recorded 50% maturity during both seasons inside polyhouse. During on-season, NS 183 was to mature early in open field. During off- season fifty percent head formation was not observed in open field in any of the hybrids.

Net head weight was maximum for NS 43 inside polyhouse (off- season) and during on-season it was maximum for NS 35 under both growing conditions. Head shape of all the hybrids except NS 43 was found to be conical during off- season inside rain shelter. But NS 43 formed drum head shaped heads. NS 183, NS 35 and Disha formed round shaped heads under both growing conditions while NS 43 formed drum head shaped heads during on-season.

During off- season, inside the rain shelter maximum head length was observed for the hybrid Disha (14.26cm) and it was on par with NS 183 (13.93cm).Disha recorded maximum head length

inside the rain shelter during on- season also (16.25cm) and it was on par with NS 183 (15.91cm) and NS 35 (15.54cm). Core length inside the rain shelter during on- season was minimum for NS 43 (7.87cm) and it was on par with NS 183 (8.79cm) and NS 35 (7.87cm). During off- season, inside the rain shelter harvest index was found to be maximum for NS 43 (67.70) which was on par with NS 183 (60.46). Pest and disease incidence was more in open field crop during both seasons.

The daily weather parameters recorded inside and outside the polyhouse were used to compute the crop weather relationship. There was significant correlation between the weather parameters and characters like days to fifty percent head formation and days to fifty percent head maturity. Benefit –cost ratio was maximum for open field crop (2.66) during on- season.

It can be concluded that NS 43 is ideal for protected cultivation during off- season, while NS 35 is suitable for on- season cultivation under both growing conditions. Further, off- season cultivation of cabbage in rain shelter offer much scope for self employment generation for the unemployed youth.