EVALUATION OF CABBAGE (*Brassica oleracea* L. var. *capitata)* FOR SOUTHERN KERALA

by

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(2011-12-113)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Evaluation of cabbage (*Brassica oleracea* L. var. *capitata)* for southern Kerala"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Dedicated to

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LIST OF ABREVIATIONS

%	-	per cent
µg	-	microgram
μm^2	-	micro square metre
CD	-	Critical difference
cm	-	centimeter
et al	-	And others
Fig.	-	Figure
g	-	gram
GA	-	Genetic Advance
GCV	-	Genotypic Coefficient of Variation
h	-	hour
H^2	-	Heritability
ha	-	hectare
I.U	-	International Unit
KAU	-	Kerala Agricultural University
kg	-	Kilogram
m	-	metre
mg	-	milligram
min	-	minutes

ml	-	millilitre
mm	-	millimeter
nm	-	nanometer
^{o}C	-	Degree Celcius
PCV	-	Phenotypic Coefficient of Variation
s	-	seconds
SE	-	Standard error
t	-	tons
Var.	-	variety

INTRODUCTION

1. INTRODUCTION

Cabbage (*Brassica oleracea* L.var.*capitata*) is a popular green leafy vegetable belonging to the family Brassicaceae. It is a hardy cool season annual vegetable, but behaves as a biennial when grown for seed production. The head consisting of thick leaves overlapping tightly on growing bud is the economic part used as vegetable.

Cabbage is an excellent source of vitamins and minerals. It also contains number of antioxidative compounds. 100 g of cabbage contains 5.3 g carbohydrates, 1.4 g protein, 0.2 g fat, 80 IU vitamin A, 0.06 mg thiamine, 0.05 mg riboflavin, 100 mg ascorbic acid, 46 mg calcium, 0.8 mg iron, 38 mg phosphorus (Bose and Som, 1993). The peculiar flavour of cabbage head is due to presence of sinigrin which carries sulphur (Rana, 2008). Cabbage is a source of indole-3-carbinol, a chemical which boosts DNA repair in cells and appears to block the growth of cancer cells.

Cabbage is cultivated in an area of 3.69 lakh ha with a production of 79.49 lakh MT (NHB, 2011). Indian cabbage has undergone fast diversification within a short period of two centuries of its introduction (Seshadri and Chatterjee, 1996). In India cabbage varieties are classified in to early, mid and late. With the development of tropical cabbage varieties at IARI, New Delhi, the cultivation has spread to the non traditional areas in South India including Karnataka, Tamil Nadu and Kerala.

Cabbage is comparatively a new crop in Kerala particularly in the plains. The high range regions of Kerala offers great scope for cultivation of cabbage and it is cultivated in the cool climate of the hill tracts of Idukki and Wynad districts. But with the development of tropical varieties and hybrids which can grow and form head at high temperatures, cultivation of cabbage was made possible in the plains of the state.The research on this crop in Kerala is rather negligible except for the evaluation trials conducted at the College of Horticulture, Vellanikkara, Thrissur and Agricultural Research Station Mannuthy. They had identified NS 43, NS 160 and NS 183 as potential cabbage varieties suitable for plains of Kerala.

Time of planting is another important factor which determines the head formation, yield and quality of cabbage. The most suitable period for the cultivation of cabbage under the Kerala conditions is from October to March.

There exists considerable variability in cabbage genotypes in respect of yield and quality attributes. The information on nature and magnitude of variability for different characters present in tropical cabbage varieties will help in its crop improvement. The information on varietal suitability and best date of planting for a particular variety will be useful for the farmers to cultivate them in the plains of the state which reduces the consumer depends on supply from neighbouring states.

Taking into consideration these aspects, the present study was undertaken with the following objectives:

- To identify superior varieties with high yield, quality and less incidence of pests, diseases and physiological disorders.
- To identify the most suitable time of sowing of these varieties.
- To study the interaction effect of sowing dates and varieties.
- To assess the genetic variability present in tropical varieties.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cabbage is the most important vegetable commercially produced and consumed in India. The crop requires cool moist weather for producing best quality heads. Indian cabbage has undergone fast diversification within a short period of two centuries of its introduction (Seshadri and Chatterjee, 1996). Based on maturity of head after transplanting, cabbage varieties are grouped into early, mid and late season varieties. With the development of tropical cabbage varieties at IARI, New Delhi, the cultivation has spread to the non traditional areas in South India including Karnataka and Tamil Nadu. Cabbage is comparatively a new crop in Kerala particularly in the plains and their cultivation in turn would reduce the consumer depends on supply from neighbouring states.

In this chapter, effort has been made to review the available literature pertaining to the effect of date of sowing and varieties on the yield of cabbage. The literature is reviewed under the following headings:

2.1 Influence of varieties on yield and quality

2.2 Influence of date of sowing and climate on yield and quality

2.3 Interaction between varieties and sowing dates

2.4 Incidence of physiological disorders

2.5 Incidence of pests and diseases

2.6 Genetic parameters

2.1 Influence of varieties on yield and quality

Bhardwaj (1996) evaluated twenty divergent genotypes of cabbage and found significant difference among the genotypes tested. Evaluation of twenty five diverse genotypes of cabbage including two land cultivars (Golden acre and Pride of India) showed highly significant differences among genotypes for all traits. The genotypes Golden Acre, EC-271632, Express Mail, 83-5 and Pusa Mukta performed well for marketable maturity, head compactness, head size, net head weight and per cent compact heads respectively (Kumar, 1998).

Nathoo *et al*. (1999) evaluated five varieties of cabbage and found significant differences between the locations and the varieties tested. Chaubey (1999) carried out stability analysis for maturity and vegetative characters in 23 genotypes of cabbage and revealed significant difference among the genotypes for all the traits except stalk length and core length. The genotypes Musketeer, Krishna, Red Ruby, Hari Rani Gold and T-621 showed stable performance.

Rai and Singh (2000) conducted an experiment with nine genotypes of cabbage and found that both gross and net head weight, number of non-wrapper leaves and stalk length mainly contributed to its yield. Chaubey (2000) carried out stability analysis of yield and quality contributing characters in 23 genotypes of cabbage and best results for gross weight, polar diameter, head shape index and ascorbic acid content were obtained for Green Challenger, Hari Rani Gold, Mitra, Red Ruby respectively.

Sharma (2001) reported that out of 30 genotypes of cabbage evaluated for traits like gross head weight, net head weight, head compactness, head shape index, stump length, total yield per plot, number of non-wrapper leaves, total soluble solids, core size, leaf size index, heading percentage, days to marketable maturity the performance of Winter Keeper, Hansens Progress, Autumn Victory, Autumn Supreme, Bunkers Hill, Golden Acre Early Forcing and Robinson champion was found good. Among these seven genotypes Hansens Progress was found to be best for highest significant yield and other horticultural traits. Sharma (2001) evaluated four cabbage hybrids in two different seasons (summer and winter) and found that hybrids Green Challenger and Varun had equal potential to yield during both the seasons.

Gopalakrishnan (2004) conducted an experiment in the Regional Agricultural Research Station, Ambalavayal on adaptability testing in cabbage and revealed that maximum yield was obtained in the variety “September”(38.28t/ha).This was closely followed by Sri Ganesh, Hari Rani, IAHS 2 and Hybrid 43 which were on par in productivity (25-27 t/ha). September is a flat head variety with an average head diameter of 16.5cm.

Sharma *et al.* (2006) conducted stability analysis for marketable head yield and its contributing horticultural traits in 11 genotypes of cabbage and revealed that genotypes KGAT-III and Pusa Muktha were suitable for higher marketable head yield along with stability for important horticultural arttributes.

Ijoyah and Rakotoavo (2007) compared the yield performance of five cabbage varieties at Seychelles and found that variety Gloria Kid YR performed best and capable of giving satisfactory yield under open field condition. Wambani *et al.* (2007) evaluated six improved cabbage (*Brassica oleracea* var. *capitata*) varieties (Gloria F1, Pruktor F1, Riana F1, Fortuna F1, Green Challenger F1 and Victoria) and found that Gloria had the highest fresh marketable heads followed by Riana and Pruktor. Sharma (2007) evaluated twenty five exotic lines of cabbage and revealed that all characters under study contributed up to 99 per cent towards the variation in yield.

In a study at Tanzania by Adeniji *et al.* (2009) observed that varieties Gloria F1 and Victoria F1 were best for head yield during long rainy season, while Quick Start and Rotan performed best for head yield during short rainy season. For multiple characters (taste, head shape and firmness) Summer Summit F1 was best. Tropical Delight was preferred for head size, firmness and low incidence of loose heads.

Significant differences were obtained for head width and head length of three cabbage varieties and the variety ‘Paradox’ produced the longest head length, largest head width, highest head weight and best yield potential (37.7 tonnes/hectare) (Richardson, 2012). An experiment was conducted to investigate the genetic variability for morphology and quality traits in 30 diverse cabbage genotypes (Meena *et al.,* 2012). Wide range of variation was observed for almost all morphological and qualitative traits for yield, days to maturity and leaf length.

Hasan and Solaiman (2012) conducted varietal evaluation in cabbage and found that variety Atlas 70 achieved the highest plant height, leaf length with petiole, stem length, diameter of head, weight of whole plant, gross yield and marketable yield. Narayanankutty *et al.* (2012) evaluated 28 cabbage varieties and identified NS 43, NS 160 and NS 183 as suitable varieties for cultivation under warm humid tropics of Kerala.

Kumar *et al.* (2013) evaluated fourteen genotypes of cabbage and revealed significant difference among the genotypes for all the characters. Among all the genotypes Pusa Ageti was found best for early maturity. Leaf size index and heading percentage was highest in AC-83 and AC- 1 respectively. Overall gross head weight, net weight, yield per plot and per hectare was found maximum in genotype AC-16.

2.2 Influence of date of sowing and climate on yield and quality

Environmental factors like air, soil, temperature, quality, intensity and duration of radiation and humidity affects physiological functioning of cabbage. Since, the effects of weather on head yield are complex, deeper and clear understanding of how the climatic factors affect the growth and yield of cabbage are needed.

Cabbage varieties are grouped into early, mid and late season varieties on the basis of temperature requirement for head formation (Seshadri and Chatterjee, 1996). Varieties have been evolved for different seasons in India: early varieties include Golden Acre and Pride of India, mid season varieties include Glory of Enkhuizen and September and late season varieties include Pusa Drumhead.

2.2.1 Influence of date of sowing

Time of sowing is a major factor which determines the head initiation development and quality. The influence of time of planting on cabbage varieties were studied by different workers (Everaarts and Moel., 1991; Futane *et al*., 1995; Sharma, 2001; Radovich *et al*., 2005).

Kapelev (1964) studied effect of planting dates and weather conditions on the growth and development of cabbages and reported that cabbages planted on November showed less tendency to bolt than those planted in October.

Everaarts and Moel (1991) compared the influence of different dates of planting on yield and shape of cabbage cultivars Castello and Bartolo. They reported that early planting (May 10th) increased head weight and size in cabbage and showed a decline in yield with later planting. In an experiment conducted at Akola to study the effect on planting dates on ratoon cabbage with four planting dates it was found that planting on October 27th resulted in a significantly higher percentage of ratoon-forming plants, larger ratoon heads and higher yield (Futane *et al*., 1995).

A study conducted by Cebula *et al.* (1996) revealed that delayed planting dates in cabbage brought significant decrease in yield.

Processing yield, total yield, final dry weight, leaf thickness, stem weight, leaf weight, root weight, leaf area, net assimilation rate, relative growth rate, total plant weight was influenced by planting times and planting densities in Brussels sprouts and broccoli (Moel and Everaarts, 1998).

Kumar *et al.* (2000) reported that marketable yield was significantly higher in the crop transplanted in March than April but at par with May transplanted crop.

Sharma (2001) evaluated four dates of transplanting (8th Oct., 18th Oct., 28th Oct. and 7th Nov. during winters and 7th Apr., 17th Apr., 27th Apr. and 7th May during summers) and four cabbage hybrids and observed that irrespective of the season, growth, yield and quality characters were significantly favoured with earlier dates of transplanting i.e. 8th October in winters and 7th April in summers.

Pradeepkumar *et al*. (2002) conducted adaptability trail of cauliflower genotypes in the high ranges of Kerala. They reported that synthetic cultivars belonging to the early maturing type of tropical cauliflower performs better under high range conditions of Kerala. The performance of mid season and late types was poor in all the planting dates. Even for the tropical cauliflower types a difference of 20 days in planting resulted in direct reduction in production of curd and its size. Early planting (first week of October) is ideal for realizing potential yields in cauliflower under high range situations of Kerala.

Kleinhenz and Wszelaki (2003) evaluated seven cultivars of fresh market-type cabbage planted in May and June and reported that the PD x C interaction was significant for head density, the ratio of head polar and equatorial diameter, and core base width. May planting resulted in greater yield and larger, heavier heads with greater polar/equatorial diameter values relative to June planting. The number of head and core traits affected by planting date differed among cultivars.

Yields of marketable cabbage heads were the highest when planted in November and the yields decreased from December and the lowest yield was recovered in crops planted in March (Chavan *et al*., 2004).

The effects of planting date (18 July and 3 August) on characteristics and yield components of Brussels sprouts (cv. De La Halle) were studied and found that planting date had a significant effect on plant weight and height, number of leaves, fresh and dry weight of leaves and stems, number of bud and bud weight, time from planting to bud initiation and bud initiation to harvest (Kurtar, 2006).

Pankaj (2007) reported that significantly higher marketable cabbage yield was recorded in June second week (267.47 q/ha) and May second week (260.07 q/ha) transplanted crop. Zhang *et al.* (2008) reported that middle of June was the best suitable sowing period for cabbage in Songming.

Singhal *et al.* (2009) studied the effects of planting dates on performance of broccoli and found that planting on 15th October resulted in greater plant weight and net head weight. It was also noticed that longest shelf life was obtained in planting on 14th November.

Zagade *et al.* (2010) reported that sowing cabbage crop on October 15th produced significantly higher cabbage yield than delayed sowing on 30th October and 15th November.

Bana *et al.* (2012) reported that highest yield of cabbage heads was obtained from the crop transplanted on 10th October, while minimum yield was in late transplanted crop. Kałuzewicz *et al.* (2012) studied variation in length of the period from planting to head initiation in broccoli and shortest period from planting to initiation was when the plants were planted in April and June (17-18 days). The length of the period from planting to head initiation depended on mean daily air temperature.

Karthika *et al.* (2013) reported significant difference between different planting dates for curd weight of cauliflower in the central region of Kerala. Among the different planting dates November 1st was found to be ideal (532.2g per plant) for getting higher economic yield.

2.2.2 Influence of climate

Hara and Sonoda (1982) reported seasonal environmental conditions affect the head formation of cabbage plants. Among the environmental factors, temperature is the most influential through its effect on carbohydrate production and consumption of plants. Rabino and Mancinelli (1986) reported that temperature affects light-dependent anthocyanin production in cabbage seedling.

Sharma and Verma (2000) conducted an experiment to identify the suitable varieties of cabbage for dry, temperate, high hills of northern India. The hybrid Bahar and Pusa Muktha recorded a yield of 30.79 and 22.27 tonnes/ha compared to Golden Acre (14.39 tonnes/ha). Differences in daylight hours and temperatures also affect the number of days to maturity (Greenland *et al.*, 2000)

High temperature had a negative effect on bud initiation in brussels sprouts and thermal time needed for vegetative growth was higher than bud initiation to harvest. Brussels sprouts requires a period of low temperature (12-17^{0}C) for proper bud initiation (Vural *et al.,* 2000). Cooper (2000) reported that optimal temperature range of 20-30 ^{0} C is ideal for cabbage.

Sharma and Sharma (2001) conducted a study and found that continuously increasing temperature of summer have boosted up the growth of later planted cabbage crop, thereby ensuring early maturity.

Ajithkumar (2005) reported that weather had played a significant role in deciding the yield of cauliflower. The LAI values revealed that the development of the leaf area remained slow during the early vegetative growth period (juvenile phase) up to 30-40 days after planting and thereafter, increased sharply with the advancement of crop age.

A study was conducted to determine relationship between yield and seasonal weather patterns of five cruciferous vegetables (broccoli, cabbage, cauliflower, radish and rutabaga) and their yields showed roughly a 10 % yield loss for every 1^{0}C increase, when temperature reached 30^{0}C or above during the growing season (Warland *et al.,* 2006).

2.3 Interaction between varieties and sowing dates

Jonassen (1976) studied the effect of planting and harvesting dates on the yield of cabbage and found that the earliest dates for planting in the field (9th and 14th May) resulted in best yields.

Home and Waters (1994) evaluated cabbage cultivars during two winter seasons (November & February) and revealed that cultivar PSR 18589 and Pennet showed good performance in both the seasons.

Futane *et al.* (1995) conducted an experiment in which cabbage cultivars Sri Ganesh Gol, Kranti, Maharani, Danish Supreme and Pride of India were planted on 27th October, 17th November, 7th December and 27th December. Planting on October 27th resulted in a significantly higher percentage of ratoon-forming plants, larger ratoon heads and higher yield than planning on other dates.

Danish Supreme was the most productive cultivar and Sri Ganesh Gol was the least productive.

Moel and Everaarts (1996) carried out an experiment during two seasons to study growth, development and yield of early maturing white cabbage cultivar Castello, and the late maturing cv. Bartolo, in relation to time of planting during the season. Results indicated that for both cultivars, planting late in the season resulted in a substantially reduced yield at the end of the season. When harvested at an average weight of 1.1 kg per head, effects for cv. Castello on necessary period of growth were small. The onset of rapid head growth was earlier with cv. Castello and this cultivar partitioned a greater part of total weight to the head as compared to cv. Bartolo. With planting late in the season quality of the head of cv. Bartolo was unacceptable.

Shaker (1999) evaluated the effect of planting date (first week of November, December and January) on cabbage cv. Balady and found that early planting significantly enhanced the growth of cabbage. Kumar *et al*. (2000) reported that cv. Golden Acre transplanted in March in Himachal Pradesh produced significantly higher marketable heads than those planted in April.

Chaubey *et al*. (2000) conducted stability analysis in 23 genotypes of cabbage over 8 environments during winter spring and spring summer season and revealed that mean squares due to G x E (Liner) was significant for all the characters except equatorial diameters of heads. None of the genotypes were found stable for yield, percentage of marketable heads and net weight of heads.

A experiment was conducted by Sharma (2001) to study the effect of four dates of transplanting (8^{th} Oct., 18^{th} Oct., 28^{th} Oct. and 7^{th} Nov. during winters and 7^{th} Apr., 17^{th} Apr., 27^{th} Apr. and 7^{th} May during summers) and four hybrids (Bajrang, Green Challenger, Bharati and Varun) on growth, yield and quality characters of cabbage. It was found that earlier dates of transplanting (8^{th} Oct. in winters and 7^{th} April in summers) and hybrids Green Challenger and Varun yield significantly well.

Kleinhenz and Wszelaki (2003) evaluated seven cultivars of cabbage planted in May and June and found that May planted cabbage showed greater yield and larger, heavier heads with greater polar/equatorial diameter values.

Radovich *et al*. (2005) conducted a study to determine the independent and interactive effect of planting date (PD) cultivar (C) on the total glucosinolate concentrations in cabbage. Six commercial fresh market cabbage cultivars were planted in May and June. Total glucosinolate concentrations were significantly affected by PD and C, but the PD x C interaction was not significant.

Chaubey (2006) evaluated twenty three genotypes of cabbage. The spring-summer planting resulted in significantly earlier maturity as compared to winter-spring planting with the difference of two weeks. Number of non-wrapper leaves was always higher during summer than in winter season at any fertility levels. It was also observed that the most of the early maturing genotypes showed lower number and the late maturing ones showed higher number of non-wrapper leaves is considered as an undesirable traits.

Adeniji *et al*. (2009) carried out a participatory evaluation of varieties for adaptation and yield. Results indicated that for each season marketable head yield differed significantly ($P<0.05$) among the varieties. During the long rainy season, Gloria F1 and Victoria F1 were best for head yield; while Quick Start and Rotan performed best for head yield during the short rainy season. For multiple characters (taste, head shape and firmness), Summer Summit F1 was best. Tropical Delight was preferred for head size, firmness and low incidence of loose heads. Gloria F1 was identified as an early maturing variety with good head solidity. Good-tasting cabbage varieties were Summer Summit, Summer Glory and Bonus.

Singh *et al.* (2010) studied the effect of transplanting dates on plant growth yield and quality traits of cabbage cultivars and reported that maximum yield potential of various cultivars was realised by transplanting of cabbage seedling on December 1st. The most compactable head was observed for Indam 1299 followed by Golden Acre, NS-160, KGMR-1 and lowest in Ryozeki. Zagade *et al*. (2010)

reported that sowing of cabbage cv. Golden acre on 15^{th} October produced significantly higher yield.

Khan and Yadav (2010) studied effects of planting dates (15 Oct., 30 Oct and 15 November) on performance of broccoli variety Fiesta and revealed that maximum plant height , number of leaves per plant, early curd initiation and early curd maturity were recorded when transplanted on 15^{th} October to 30^{th} October.

In a study conducted at Solan with cabbage cv. Pride of India transplanted on seven planting times from 3^{rd} week of June to 1^{st} week of August Dev (2011) found that cabbage seedling transplanted in the second week of July produced significantly higher percentage of mature normal heads

2.4 Influence of season on incidence of physiological disorders

Physiological disorders of cole crops are abnormalities in leaf and stem morphology, colour, or both which are not caused by infectious diseases or insects. The abnormalities occur as a result of environmental stress, nutritional deficiencies or excess on the plant. Various physiological disorders of cabbage includes blindness, bolting, boron deficiency, bursting/split heads and tip burn. (Verma, 2009).

Blindness disorder occurs in cabbage and results in no head formation or multiple small heads form. Pre- and/ or post transplanting factors, such as damage to the terminal growing point due to low temperature, cutworm damage or rough handling of transplants results in blindness (Verma, 2009).

Masarirambi *et al.* (2011) reported physiological disorders like head splitting, blindness, vein streaking necrosis and necrotic spot in cabbage and suggested measures to alleviate these physiological disorders.

Heads split or burst usually due to heavy rains or overwatering or delayed harvest of cabbage. Rapid growth causes splitting of heads. Early maturing cultivars are most susceptible. This disorder may be alleviated by avoiding overwatering and maintaining uniform growth with proper irrigation. Harvesting on time and use of resistant cultivars preferably late cultivars may help to alleviate this problem (Masarirambi *et al*., 2011).

2.5 Influence of season on incidence of pests and diseases

2.5.1 Incidence of pests

The major pests in cruciferous vegetables include diamond back moth (*Plutella xylostella*), tobacco caterpillar (*Spodoptera litura*), cabbage aphid (*Brevicoryne brassicae*, *Myzus persicae*), cabbage butterfly (*Pieris brassicae*) and cabbage head caterpillar (*Corcidolomia pavonana*) (Loganathan, 2002).

2.5.1.1 Leaf caterpillar (*Spodoprtera litura)*

Seasonal flight activity in *Spodoptera litura* in cauliflower fields indicated a peak of activity in November-December and February-March, which shows the survival of adults in cold winter temperatures (Ali, 1989).

Soujanya *et al*. (2004) reported that novaluron 0.005% + indoxacarb 0.00725% + and indoxacarb 0.0145% were found to be most effective against *Spodoprtera litura* on cabbage. Varalekshmi *et al*. (2006) reported that favourable time for multiplication of *Spodoprtera litura* is from December to January.

In an experiment conducted to determine the seasonal incidence of *Spodoptera litura* on cauliflower, it was found that the larvae could be seen from 36th standard week onwards in a fluctuating manner and the population attained its peak during the 43rd standard week (T_{max}= 39.5°C and T_{min}= 20.7°C) and declined gradually after the 46th standard week (Monobrullah *et al*., 2007).

The feeding pattern of polyphagous pest, *Spodoptera litura* revealed that the larvae prefers mostly to feed on cauliflower and least preference for castor (Chand and Tripathi, 2008).

2.5.2 Incidence of diseases

The major diseases in cruciferous vegetables include club rot (*Plasmodiophora brassicae*), black rot (*Xanthomonas campestris pv. campestris*), stalk rot (*Sclerotinia sclerotiorum*), downy mildew (*Pernospara parasitica*), leaf spot and head rot (*Alternaria brassicae*) and rhizoctonia blight (*Rhizectonia solani*).

Optimum temperatures for spore production of *Alternaria* spp. are 24°C–28°C, and new spores can be produced in 7–10 days of infection under favorable temperature conditions for penetration and germination (Kucharek, 2000).

Massomo (2003) conducted a study to manage black rot of cabbage, caused by *Xanthomonas campestris pv. campestris* (Xcc) and he screened thirty-one local and introduced cabbage varieties. He found that Amigo F1, Maja F1, Rotan F1, Ducati F1, Adelita F1, Bravo F1, Blue Thunder F1, Fortress F1, JK-1 F1, Gianty F1, T-689 F1, N-9690 F1, N 66 F1 and Riana F1 showed partial resistant.

Alternaria epidemic occur under high relative humidity condition (>87%) and high temperatures *(A. brassicicola)* or moderate *(A. brassicae).* For the infection, at least, 9 h of free water in the surface of the plant is necessary (Mehta *et al*., 2005)

2.6 Genetic parameters

2.6.1 Variability

The efficiency of selection in crop improvement programmes largely depends on the extent of genetic variability present in the population. Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement. Larger the variability better are the chances of identifying superior genotypes.

The variation present in the plant population is of three types viz., phenotypic, genotypic and environmental. Of these the genetic variance can be further partitioned to additive, dominance and epistatic variance components. The phenotypic, genotypic and environmental coefficient of variation (PCV, GCV and ECV respectively) gives an idea about the magnitude of variability present in the population.

Genetic variability among cabbage genotypes in India was studied by Sharma *et al.* (2000), Rai and Singh (2000), Sharma (2001), Balkaya *et al.* (2005), Sharma (2007), Atter *et al.* (2009), Singh *et al*. (2010) and Meena *et al.*(2012).

Bhardwaj (1996) revealed that phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for bolters percentage, stalk length and stalk rot incidence, while moderate estimates were recorded for the remaining characters.

Kumar (1998) reported that phenotypic and genotypic coefficients of variation were high for head compactness, gross head weight, per cent bolters and total yield/plot.

Rattan (2001) evaluated twenty three diverse genotypes and analysis of variance showed highly significant differences among the genotypes for all the traits under study. Yield per plant had significant positive correlation with penduncle length, central head size and plant frame. Plant frame was significantly correlated with plant height, leaf area and harvest duration while central head size had positive and significant correlation with peduncle length. Sharma (2001) reported that phenotypic and genotypic coefficients of variability were high for net head weight and total yield/plot.

Kalia and Shakuntla (2002) revealed that phenotypic and genotypic coefficients of variation were high for leaf area, plant height, terminal head weight, head compactness, marketable yield/plant and mean spears weight.

Vaidya (2003) revealed that variances due to general and specific combining ability were significant for all the characters suggesting that both additive and non-additive genes were important for manifestation of the traits. The magnitude of variances due to SCA was greater than variance due to GCA indicating the preponderance of non-additive gene action. The line PK-1 was good general combiner for yield and its contributing traits

Kumar (2004) revealed that high coefficient of variation was observed for net head weight and yield per plot and moderate coefficient of variation were observed for days to marketable maturity, stump length, number of non-wrapper leaves, plant frame, head compactness, gross head weight, leaf size index, heading percentage and core size.

Sharma *et al*. (2006) reported that analysis of variance indicated highly significant difference among genotype and diversity in environment for all the traits expect for net weight of head among genotypes and polar diameter and equatorial diameter among environments.

Antonova (2009) reported that highest phenotypic and genetic coefficient of variation more than 30% was determinate for the weight and diameter of head. Broad-sense heritability was high for most of the investigated characteristics and varied from 51% to 92%.

Atter *et al*. (2009) revealed that highest estimates of PCV and GCV for marketable yield followed by net weight of head, gross weight per plant and low for harvest index followed by days to marketable maturity and marketable head.

Meena *et al.* (2009) revealed that positive and significant association of yield was observed with all the characters except days to maturity and stalk length at both genotypic and phenotypic level which indicates that selection based on these characters either in combination or alone will result in identifying the genotypes having high yield potential.

Singh *et al.* (2011) evaluated 36 diverse cabbage genotypes. The phenotypic and genotypic coefficients of variation were high for carotenoids, stalk length, head compactness, gross plant weight, net head weight, dry matter, core length, plant height and equatorial diameter and low of days to 50% maturity, number of non-wrapper leaves, frame spread and ascorbic acid. The expressions of all the studied traits except ascorbic acid, harvest index and head compactness were less influenced by environment, as evident from meagre difference between respective PCV and GCV.

Meena *et al.* (2012) reported genotypic correlation coefficient higher than the corresponding phenotypic correlation coefficient for all the parameters. The dray matter had significant and positive correlation with all quality traits.

Fourteen diverse genotypes of cabbage were evaluated to know the nature and magnitude of variability for stump length (cm), number of non wrapper leaves, plant spread (cm^2), leaf size index (cm^2), gross weight of head (g), net weight of head (g), heading percentage, days to marketable maturity, core length (cm), yield per plot (kg) and per hectare (q). The analysis of variance revealed the significant differences among all genotypes for all the traits under study (Kumar *et al.*, 2013).

2.1.2 Heritability (H^2) and genetic advance (GA)

Heritability and genetic advance are important selection parameters. The ratio of genetic variance to phenotypic variance is known as heritability. Heritability (%) was categorized into low (0-30%), moderate (30-60%) and high (above 60%) as suggested by Robinson *et al.* (1949). Higher heritability indicates the least environmental influence on the characters. The difference between the mean phenotypic value of the progeny of selected plants and the base or parental population is called as the genetic advance. The genetic advance was categorized into low (<20%) and high (>20%) as suggested by Robinson *et al*. (1949).

Bhardwaj (1996) reported high heritability coupled with moderate genetic gain for characters viz. total yield per plot, days to marketable maturity, core size, leaf area index, net head weight, gross head weight and head size. Kumar (1998) observed highest broad sense heritability for head shape index while genetic gain was highest for per cent bolters.

Rattan (2001) reported high heritability for central head size, harvest duration, head compactness and leaf area, whereas high genetic gain was observed for head compactness and harvest duration. Highest broad sense heritability was observed by Sharma (2001) for gross head weight followed by days to marketable maturity, while genetic gain was highest for net head weight.

Kalia and Shakuntla (2002) reported that high heritability associated with low genetic advance for days to marketable maturity and moderate heritability coupled with low genetic advance for stem diameter and harvest index may be attributed to non-additive gene action.

Kumar (2004) recorded a high heritability and genetic gain for gross head weight, net head weight and yield per plot.

High heritability was noticed by Atter *et al.* (2009) for shape of head followed by compactness of head, marketable yield and gross weight per plant. High genetic advance was observed for marketable yield, whereas it was low for days to marketable maturity, marketable head, length of stalk and harvest index and indicates that these traits are likely to respond better to selection. Yield registered high estimates of heritability while gross weight showed low heritability (Meena *et al*., 2009).

Singh *et al.* (2011) recorded moderate to high heritability and high genetic advance for carotenoids, dry matter, plant height, gross plant weight, net head weight, stalk length, core length and head compactness. High estimates of heritability were noticed for yield whereas it was low for gross weight were recorded by Meena *et al.* (2012). High heritability coupled with moderate genetic gain was observed for gross head weight, net head weight, yield per plot and per hectare (Kumar *et al.,* 2013).

2.1.4 Correlation studies

Selection of desirable genotypes is the principal step of crop improvement. Most of the economically important characters like yield is an extremely complex trait and is the result of many growth functions of the plant. An estimation of inter-relationship of yield with other traits is of immense help in any crop improvement programme. Correlation studies would facilitate effective selection for simultaneous improvement of one or many yield contributing components (Dewey and Lu, 1959).

Knowledge of association between component characters and between component characters is essential for yield improvement through selection programme. The correlation coefficient analysis measures the mutual relationship between various characters and it determines the component traits on which selection can be relied upon the effect of improvement. The coefficient of correlation can vary from +1 to -1.

Total yield per plot was found to be positively and significantly correlated with net head weight, gross head weight, head size, core size and early yield (Bhardwaj, 1996).

In a study conducted by Kumar (1998) found that yield/plot had significant positive correlation with net head weight, while head compactness had significant negative correlation with head size.

Yield per plot had significant and positive correlation with net head weight, gross head weight, leaf size index and heading percentage (Sharma, 2001).

Correlations of various traits were studied in cabbage. The genotypic correlations were higher than phenotypic ones. The total yield/plot had positive and significant correlations with early yield, head size, and gross head weight at both phenotypic and genotypic levels. Hence, selection of genotypes with larger head size and more head weight would be effective to obtain high-yielding genotypes (Singh, 2002).

Abbey and Manso (2004) conducted a comparative study to determine the degree and direction of linear association ($Y = a + mX$) among yield and yield components of two cultivars of cabbage and they showed high positive linear correlation between plant weight and head width. Head width, head length, non-wrapper leaf weight, head weight and yield showed positive correlation.

Sharma (2007) revealed that marketable yield had positive and significant association with gross weight, net weight of head, non wrapper leaves and compactness of head there by indicating that these traits had certain inherent relationship with yield.

Antonova (2009) reported that relationships between vegetation continuation and cabbage weight, leaf rosette weight with cabbage weight and diameter, cabbage weight with head diameter and shape and the correlation between cabbage shape and firmness are with high coefficients of genetic correlations.

In a study conducted by Sharma (2010) reported that genotypic correlation coefficient were higher in magnitude than the corresponding phenotypic ones, there by suggesting strong inherent association between various characters studied. Correlation studies conducted in 36 genetically diverse exotic and indigenous genotypes of cabbage indicated 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)

Parkash and Meena (2011) reported all the traits were significantly and positively correlated with head weight except number of leaves.

Adzic *et al.* (2012) conducted a study to determine the correlation of important agronomic characteristics and yield of medium late genotypes of head cabbage (*Brassica oleracea* var. *capitata* L.), and found that correlation analysis show 30% of estimated correlations were statistically significant. Head weight and head height, showed the highest correlation coefficients with the yield.

Meena *et al*. (2012) revealed that positive and significant association of yield was observed with all the characters except days to maturity and stalk length at both genotypic and phenotypic level.

Cervenski *et al.* (2012) studied correlation of cabbage traits in different maturity groups and found that early cabbages had 26 significant positive correlations. Plant height and rosette diameter in the early genotypes were highly positively correlated with rosette weight, whole plant weight, head weight, usable portion of head, head height, and head diameter. Head volume in the late genotypes was highly positively correlated with rosette diameter, whole plant weight, head weight, usable portion of head, inner stem length, and head height.

2.1.2.4 Path coefficient analysis

Certain characters might indirectly influence yield, but their correlation with yield may not be statistically significant. In such cases, path coefficient analysis explained by Dewey and Lu (1959), is an efficient technique which permits the separation of coefficients into components of direct and indirect effects.

Path analysis indicated that the net head weight having maximum direct effect on total yield per plot followed by leaf area index and non-wrapper leaves (Bhardwaj, 1996). Kumar (1998) reported that head compactness had highest positive direct effect on yield per plot.

Net head weight exhibited higher positive direct effect on yield per plot followed by head compactness, heading percentage and leaf size index (Sharma, 2001).

Path coefficients analyses of various traits were studied in cabbage. The path coefficients analysis revealed that selection based on larger head size and more head weight will be effective for increasing yield in cabbage. The head size had highest positive direct effect on total yield/plot, while formulating selection indices for improvement of yield in cabbage (Singh, 2002).

The character association and path coefficient analysis was carried out after field evaluation of 36 genetically diverse exotic and indigenous genotypes of cabbage. The positive association between days to 50 % maturity and number of non-wrapper leaves suggested the selection of plants having less number of non-wrapper leaves so as to evolve early maturing genotypes. Negative association of head compactness with polar diameter, equatorial diameter, frame spread, plant height, gross plant weight and core length, on the other hand, implied to select plants with smaller measurements for the latter morphological and economic traits which will not only help in improved compactness of head but also in marketability, shelf life and consumers' preference. Gross plant weight proved to be the most effective direct selection index for genetic improvement of cabbage (Singh *et al.*, 2010)

Parkash and Meena (2011) reported Path coefficient analysis revealed that direct selection for plant weight and indirect selection for plant height, plant spread and number of leaves in the positive direction may lead to increased head weight.

2.1.4 Selection Index

The economic worth of a plant depends upon several characters so while selecting a desirable plant from a segregating population the plant breeder has to give due consideration to characters of economic importance. Selection index is one such method of selecting plants for crop improvement based on several characters of importance. This method was proposed by Smith (1937) using discriminant function of Fisher (1936). Further Hazel (1943) suggested that selection based on suitable index was more efficient than individual selection for the characters.

Radovich *et al.* (2004) found a strong curvilinear relationship (R2=0.96) between head mean diameter and head weight. Head weight, size, shape, density and core dimensions, as well as relationships among them, are also critical indicators of quality in the development, evaluation and selection of cabbage germplasm.

Sharma (2007) and Sharma *et al.* (2010) suggested that net weight of head should be given utmost importance in selection programme aimed at high yielding cabbage varieties.

Atter *et al.* (2009) reported days to marketable head, marketable head, length of stalk and harvest index are likely to respond better to selection.

In a field evaluation of 36 genetically diverse exotic and indigenous genotypes of cabbage gross plant weight proved to be the most effective direct selection index for genetic improvement of cabbage. (Singh *e al.*, 2010)

In a study conducted by Meena *et al.* (2012) observed that dry matter had significant and positive correlation with all quality traits and they suggest that these traits may effectively be used as a selection criterion for screening potential genotypes in a breeding programme.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled 'Evaluation of cabbage (*Brassica oleracea* L.var.*capitata*) for southern Kerala' was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period October 2012 to March 2013. The study was conducted for identification of tropical cabbage varieties suitable for plains of southern Kerala and o know the influence of date of planting on yield and quality and their interaction effects.

3.1 Experimental site

The experimental site was located at 8º 5' N latitude and 77º 1' E longitude at an altitude of 29 m above mean sea level. Predominant soil type of the experimental site was red loam belonging to Vellayani series, texturally classified as sandy clay loam with a pH of 5.2. The area enjoys a warm humid tropical climate.

3.2 Season

The four crops were raised as winter crop from October 2012 to March 2013.

3.3 Materials

The experimental material comprised of 11 early/ mid season cabbage varieties released by private sector. The details of varieties used for the experiment are given in Table 1.

3.4 Method

3.4.1 Design and layout

Split plot design was adopted for the layout of the experiment with sowing dates as main plot treatments and varieties as sub plot treatments. Field view of this experiment was given in Plate 1. The details of the layout were as follows:

Main plot : 4 sowing dates

Sub plots : 11 varieties

Replications : 5

Spacing : 60 x 60 cm

Plate1. Field view of experimental plot

Plants/plot : 25

Plot size : 3 x 3m

On month old seedling were transplanted into main field at a spacing of 60 x 60 cm. The crop received timely management practices as per package of practices recommendation of Kerala Agricultural University (KAU, 2011)

3.4.2 Treatments

3.4.2.1 Main plot treatments

In the main plot four sowing dates were evaluated. They are:

D1 – 1st October Sowing

D2 – 15th October Sowing

D3 – 1st November Sowing

D4 – 15th November Sowing

3.4.2.2 Sub plot treatments

In the sub plots 11 cabbage varieties were evaluated.

Table 1: Cabbage varieties used for evaluation

Sl. No.	Variety	Variety name	Source
1	T1	Summer Cross	Green Co. Ltd, Vietnam
2	T 2	New Orient	Green Co. Ltd, Vietnam
3	T 3	Gayatri	Century Seeds, New Delhi
4	T 4	Veer-333	Century Seeds, New Delhi
5	T 5	Indam 296	Indo-American Hybrid Seeds, Banglore
6	T 6	Indam Radha	Indo-American Hybrid Seeds, Banglore
7	T 7	Indam 1299	Indo-American Hybrid Seeds, Banglore
8	T 8	NS 183	Namdhari Seeds, Banglore
9	T 9	BC- 38	Green Co. Ltd, Vietnam
10	T 10	Asia Cross	Green Co. Ltd, Vietnam
11	T 11	Red C- 05	Green Co. Ltd, Vietnam

3.4.3 Observations

Five plants were selected randomly from each replication and tagged for vrecording the observations.

3.4.3.1 Vegetative characters

3.4.3.1.1 Plant height (cm)

Plant height was recorded from the ground level to the top most leaf apex of the plants and presented in centimeters.

3.4.3.1.2 Non wrapper leaves per plant

Number of non wrapper leaves per plant was recorded from all the sample plants at the harvest stage and average was worked out.

3.4.3.1.3 Gross plant weight (kg)

Whole plant weight including head was taken and recorded from all the sample plants.

3.4.3.1.4 Leaf length (cm)

The seventh leaf from top of the selected plants was used for making the above observation. The length was measured as the distance from the base of the leaf lamina to the top of the leaf at harvest stage and expressed in centimeters.

3.4.3.1.5 Leaf breadth (cm)

The width of same leaf, used for recording the length was taken at the region of maximum width at harvest stage and expressed in centimeters.

3.4.3.1.6 Leaf size (cm^2)

The product of leaf length and breadth at head harvest was calculated and expressed in cm^2.

3.4.3.1.7 Position of leaves

Position of leaves is determined in relation to head at maturity. It is categorized as:-

Type No. 1 - Erect

Type No. 2 - Semi- erect

Type No. 3 - Prostrate

3.4.3.2 Head characters

3.4.3.2.1 Days to head formation

Number of days from the date of transplanting to head initiation of observational plants was recorded and the average obtained.

3.4.3.2.2 Days to head harvest

Number of days from the date of transplanting to date of head harvest of observational plants was recorded and the average obtained.

3.4.3.2.3 Days to head maturity

Number of days from the date of transplanting to 50% of the population formed marketable heads was recorded.

3.4.3.2.4 Head depth (cm)

The vertical distance in centimeters from the top end of the head to the lowest point of the basal leaf of the half cut head.

3.4.3.2.5 Head diameter (cm)

It is taken by cutting head in to two equal halves and measuring the length at the widest portion and recorded in centimeters.

3.4.3.2.6 Head solidity

The compactness index of the head was worked out by the formula given by Pearson (1931) as given below:

$$\mathrm{Z} = \frac{\mathrm{C}}{\mathrm{W3}} \times 100$$

where, Z is an index of compactness, C is the net weight of the head and W is the average of depth and diameters of the head. A higher value of Z indicates a more compact head.

3.4.3.2.7 Core length (cm)

It is taken by cutting the heads and recording the inner stem length in head.

3.4.3.2.8 Shape of head

Based on visual observation head shape was recorded. It is categorized as –

Type No. 1 - Round

Type No. 2 - Elliptical

Type No. 3 -Flat

Type No. 4 -Obovate

Type No. 5 -Oblong

Type No. 6 -Cylindrical

Type No. 7 -Others

3.4.3.3 Yield characters

3.4.3.3.1 Net head weight (g)

The weight of head without leaves and stalk of observational plants were taken and average was worked out.

3.4.3.3.2 Gross head weight (g)

The weight of head along with leaves and stalk of observational plants were taken and average was worked out.

3.4.3.3.3 Yield per plot (kg)

It is the net weight of marketable heads per plot (3 x 3 m)

3.4.3.3.4 Harvest index (%)

It is the ratio of economic yield (net head weight) to biological yield (gross plant weight).

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

3.4.3.4 Quality characters

3.4.3.4.1 Protein

Protein was estimated by Bradford method (Sadasivam and Manickam, 1996).

Reagents:

1. Dye concentrate: 100mg of coomasie brilliant blue G 250 was dissolved in 50 ml of 95 per cent ethanol. 100ml of concentrated orthophosphoric acid was added and final volume was made up to 200 ml with distilled water. It was stored under refrigerated conditions in amber bottles. One volume of concentrated dye solution was mixed with four volumes distilled water for use. This was filtered with Whatman No.1 filter paper if any precipitate occurred.
2. Phosphate-buffer saline (PBS)
3. Protein solution (Stock standard): 50 mg of bovine serum albumin was accurately weighed and dissolved in distilled water and made up to 50 ml in a standard flask.
4. Working standard: 10 ml of the stock solution was diluted to 50 ml with distilled water in a standard flask. One ml of this solution contains 200 µg protein.

Procedure:

500 mg of the sample was weighed and ground well with a pestle and mortar in 5-10 ml of the buffer. This was centrifuged and the supernatant was used for protein estimation.

0.2, 0.4, 0.6, 0.8, and 1 ml of the working standard was pipette out into a series of test tubes. 0.1 ml of the sample extract was pipetted out into 2 other test tubes. The volume was made up to 1 ml in all the test tubes. A tube with 1 ml of water is used as blank and 5 ml of diluted dye solution was added to each tube.

This was mixed well and the colour was allowed to develop for five minutes, but not longer than 30 minutes. The absorbance was read at 595 nm. A standard curve was plotted using standard absorbance *vs* concentration. The protein in the sample was calculated using the standard curve.

3.4.3.4.2 Carotene

Carotene content of fresh leaves at harvest (30 DAT) was estimated according to the method proposed by Srivastava and Kumar (1998).

Reagents

1. Acetone
2. Anhydrous sodium sulphate
3. Petroleum ether

Procedure

5g of fresh sample was taken and crushed in 10-15 ml acetone, adding a few crystals of anhydrous sodium sulphate, with the help of pestle and mortar. The supernatant was decanted into a beaker. Repeated the process twice and transferred the combined supernatant to a seperatory funnel. 10-15 ml of petroleum ether was added and mixed thoroughly. The two layers separated out on standing. The lower layer discarded and the upper layer was collected in a 100ml volumetric flask. The volume was made upto 100ml with petroleum ether and recorded the optical density at 452 nm using petroleum ether as blank.

$$\beta \text{ carotene } (\mu g\ 100\ g^{-1} \text{ sample}) = \frac{\text{Optical density X } 13.9 \text{ x } 10^{4} \text{ X } 100}{\text{Weight of sample X } 560 \text{ X } 1000}$$

$$\text{Vitamin A (IU)} = \frac{\beta \text{ carotene } (\mu g\ 100\ g^{-1} \text{ sample})}{0.6}$$

3.4.3.4.3 Vitamin C

Vitamin C content of fruit was estimated by 2, 6-dichlorophenol indophenols dye method (Sadasivam and Manickam, 1996).

Reagents

1. Oxalic acid (4%)
2. Ascorbic acid standard: Stock solution was prepared by dissolving 100 mg of ascorbic acid in 100 ml of four per cent oxalic acid. 10 ml of this stock solution was diluted to 100 ml with four per cent oxalic acid to get working standard solution.
3. 2, 6-dichlorophenol indophenols dye: 42 mg sodium bicarbonate was dissolved in a small volume of distilled water. 52 mg 2, 6-dichlorophenol indophenols was added into this and made up to 200 ml with distilled water.

Procedure

5 ml of the working standard solution was pipette out into a 100 ml conical flask and 10 ml four per cent oxalic acid was added. It was titrated against the dye (V_1 ml). End point was the appearance of pink colour of which persisted for atleast five seconds. One gram of fresh leaf was extracted in an acid medium (4 % oxalic acid) and made upto a known volume (20 ml) and centrifuged. 5ml of the supernant was taken and titrated against was calculated the dye until pink colour appeared (V_2 ml). Ascorbic acid content was calculated using the formula.

$$\text{Amount of ascorbic acid (mg 100 g}^{-1}\text{ sample)} = \frac{0.5 \times V_2 \times \text{Vol. made up}}{V_1 \times 5\text{ ml} \times \text{weight of sample}}$$

3.4.3.5 Physiological Disorders

Number of plants showing physiological disorders were recorded and percentage worked out using the formula.

$$\text{Percentage incidence of disorders} = \frac{\text{Number of plants showing blindness}}{\text{Total number of plants}} \times 100$$

The physiological disorders observed during the crop period were as follows:

1. Blindness
2. Burst head

3.4.3.6 Incidence of pests and diseases

Number of plants affected was recorded and from this percentage of plants affected was calculated.

$$\text{Percentage of plants infected} = \frac{\text{Number of plants showing blight}}{\text{Total number of plants}} \times 100$$

The pest and diseases observed during the crop period were as follows:

1. Leaf caterpillar (*Spodoptera litura*)
2. *Alternaria* leaf spot (*Alternaria brassicae*)
3. *Rhizoctonia* blight (*Rhizoctonia solani*)
4. Head rot (*Alternaria brassicae*)

3.4.3.7 Weather parameters

Following weather parameters during the course of investigation were recorded.

1 Maximum temperature (^oC)

2 Minimum temperature (^oC)

3 Rainfall (mm)

4 Relative humidity (%)

3.4.3.8 Statistical Analysis

The technique of analysis of variance for split plot design (Gomez and Gomez, 1984) was used for analyzing the experimental data and results obtained.

Critical differences (5% and 1% levels) were worked out for multiple comparisons among the means, whenever the effects turned significant. Main plot effects, sub plot effects and their interaction effects were compared using the multiple comparisons of their respective means. The breakup of the degrees of freedom (df) in the analysis of variance with reference to the present study is furnished.

Table 2. Analysis of variance

Source of variation	Degrees of freedom	Sum of Squares	Mean Sum of Squares	F Ratio
Main plot analysis				
Replication	r-1	SSR		
Main plot treatment (A)	a-1	SSA	MSA	MSA/MSE1
Main plot error (E1)	(r-1) (a-1)	SSE1	MSE1	
Sub plot analysis				
Sub plot treatment (B)	b-1	SSB	MSB	MSB/MSE2
Interaction (AxB)	(a-1) (b-1)	SS(AB)	MS(AB)	MS(AB)/MSE2
Sub plot error (E2)	a(r-1)(b-1)	SSE2		
Total	rab-1	SST		

The best sowing date based on the analysis of variance was selected and again the data were statistically analyzed. It was done to estimate genetic parameters like variability, heritability, genetic advance, correlation coefficients, etc.

The other genetic parameters were estimated as follows: (Table 3)

3.4.3.8.1 Variance:

	X	Y ss
Environmental variance ($\sigma^2 e$)	$\sigma^2 ex = E_{xx}$	$\sigma^2 ey = E_{yy}$
Genotypic variance ($\sigma^2 g$)	$\sigma^2 gx = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2 gy = \frac{G_{yy} - E_{yy}}{r}$
Phenotypic variance ($\sigma^2 p$)	$\sigma^2 px = \sigma^2 gx + \sigma^2 ex$	$\sigma^2 py = \sigma^2 py + \sigma^2 ey$

3.4.3.8.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as:

$$GCV = \frac{\sigma_{px}}{x} \times 100$$

$$PCV = \frac{\sigma_{px}}{x} \times 100$$

Where,

σ_{gx} - genotypic standard deviation

σ_{px} - phenotypic standard deviation

$\bar{x}_x$ - Mean of the character under study

3.4.3.8.3 Heritability

$$H^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}} \times 100$$

Where, H^2 is the heritability expressed in percentage (Jain, 1982). Heritability estimates were categorized as suggested by Jhonson *et al*. (1995).

0 – 30 per cent ⟶ Low

31 – 60 per cent ⟶ Moderate

>60 per cent ⟶ High

Table 3. Analysis of Variance / Covariance

Source	Dof	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Block	(r-1)	B_{xx}		B_{xy}		B_{yy}	
Genotype	(v-1)	G_{xx}	$\sigma^2_{ex}+\sigma^2_{gx}$	G_{xy}	$\sigma^2_{exy}+r\sigma^2_{gxy}$	G_{yy}	$\Sigma^2_{ex}+r\sigma^2_{gx}$
Error	(v-1) (r-1)	E_{xx}	σ^2_{ex}	E_{xy}	$\sigma 2_{exy}$	E_{xy}	σ^2_{xy}
Total	T_{xx}		T_{xx}			T_{yy}	

3.4.3.8.4 Genetic Advances as percentage mean

$$GA = \frac{Kh^2p}{x}$$

Where, k is the standard selection differential.

K = 2.06 at 5% selection intensity (Miller *et al.*, 1958)

The range of genetic advance as per cent of mean was classified according to Jhonson *et al.* (1995).

0- 10 per cent ⟶ Low

11- 20 per cent ⟶ Moderate

> 20 per cent ⟶ High

3.3.5 Correlation

Genotypic correlation coefficient (r_{gxy}) $= \frac{\sigma gx}{\sigma gx \times \sigma gy}$ $\frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$

Phenotypic correlation coefficient (r_{pxy}) $= \frac{\sigma pxy}{\sigma px \times \sigma py}$ $\frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$

Environmental correlation coefficient (r_{exy}) = $\frac{\sigma egx}{\sigma ex \text{ X } \sigma ey}$ $\frac{\sigma_{exy}}{\sigma_{ex} \text{ x } \sigma_{ey}}$

3.3.6 Path analysis

The direct and indirect effects of yield contributing factors were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959)

3.3.8 Selection Index

The selection index developed by Smith (1937) using discriminate function of Fisher (1936) was used to discriminate the genotypes based on all the characters.

The selection index is described by the function, $I = b_1 x_1 + b_2 x_2 + \dots\dots\dots + b_k x_k$ and the merit of a plant is described by the function, $H = a_1 G_1 + a_2 G_2 + \dots\dots\dots + b_k G_k$ where $x_1, x_2 \dots\dots\dots\dots x_k$ are the phenotypic values and $G_1, G_2 \dots\dots\dots\dots\dots G_k$ are the genotypic values of the plants with respect to characters, $x_1, x_2 \dots\dots\dots\dots x_k$ and H is the genetic worth of the plant. It is assumed that the

economic weight assigned to each character is equal to unity i.e., $a_1, a_2 \dots\dots a_{k=1}$

The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b = P^{-1}Ga$ where, P is the phenotypic variance-covariance matrix and G is the genotypic variance-covariance matrix x.

RESULTS

4. RESULTS

The experiment entitled 'Evaluation of cabbage (*Brassica oleracea* L.var.*capitata*) for southern Kerala' was carried out in the Department of Olericulture, College of Agriculture, Vellayani during the period from October 2012 to March 2013.

The experiment was laid out in split plot design with four dates of sowing in main plot and 11 varieties in sub plots. The experimental data collected on vegetative characters, head characters, yield and yield attributes, quality characters, physiological disorders, pest and disease incidence were statistically analyzed and the results obtained are presented below.

4.1 Analysis of variance

Analysis of variance revealed significant difference between four dates of sowing, 11 varieties and their interactions for almost all the characters studied. The mean performance of the varieties for various vegetative, head and yield characters are furnished in Table 4 to15 and Fig.1to 9.

4.1.1. Vegetative characters

4.1.1.1 Plant height

Plant height was significantly influenced by different sowing dates and varieties (Table 4). November 1st sowing (D3) recorded highest plant height (25.79 cm) which was on par with October 15th (D2-24.28 cm) and November 15th (D4-24.05 cm) sowing. October 1st sowing (D1) recorded the minimum (23.39 cm). Among varieties Red C-05 (T11) was the tallest plant (30.75 cm) which was followed by T2 - New Orient (28.51 cm) and T8 - NS-183 (27.62 cm). Gayatri (T3) recorded minimum plant height (17.56 cm).Significant difference was observed between D x T interactions also. Maximum plant height (33.74 cm) was recorded for Red C-05 sown on November 1st (D3T11) which was on par with D2T11 (30.79 cm), D3T2 (29.92 cm), D4T11 (29.62

cm) and D4T2 (29.49 cm). Minimum plant height (15.47 cm) was recorded for VZGayatri sown on October 15th (D2T3) which was on par with D3T3 (16.82 cm) and D1T3 (16.93 cm) (Fig. 1).

4.1.1.2 Non wrapper leaves per plant

Non wrapper leaves per plant was significantly influenced by different sowing dates and varieties (Table 4). November 1st sowing (D3) recorded maximum non wrapper leaves per plant (18.11) which was on par with October 1st sowing (D1-18.00). Minimum non wrapper leaves per plant (17.04) was observed in November 15th sowing (D4) and it was on par with October 15th sowing (D2-17.20). Among varieties Red C-05 (T11) recorded maximum non wrapper leaves per plant (19.16) which was on par with BC-38 (T9 -19.03) and lowest for Indam 1299 (T7-16.01).

The interactions among various treatment combinations were also significant. Result showed that among the treatment combinations, D3T9 had maximum number of non wrapper leaves (20.40) which was on par with D1T11 (19.93). D2T5 had minimum (15.06) (Fig. 2).

4.1.1.3 Gross plant weight

Gross plant weight varied significantly for sowing dates (Table 4). November 1st sowing (D3) recorded maximum gross plant weight (1.00 kg) which was on par with October 15th sowing (D2) (0.98 kg). Minimum gross plant weight (0.84 kg) was noticed in October 1st sowing (D1) which was on par with November 15th sowing (D4) (0.87 kg).

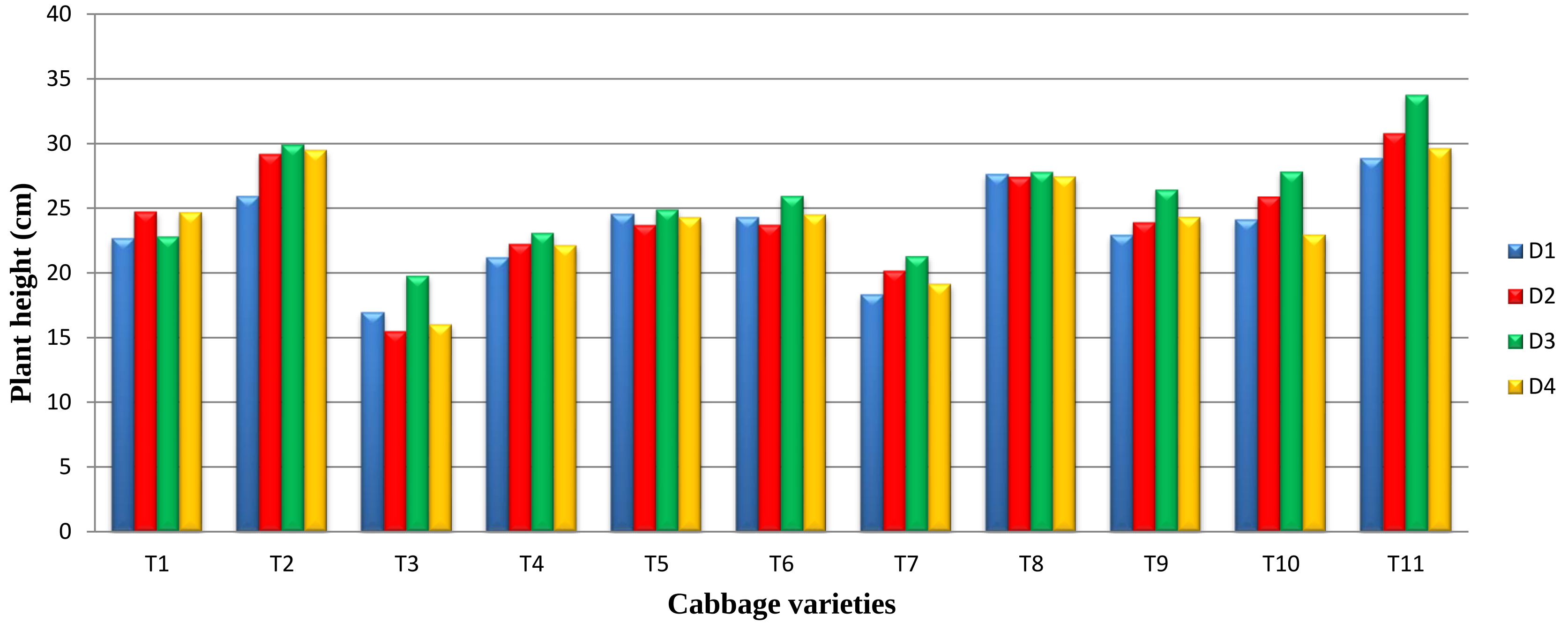
Varieties varied significantly for gross plant weight also. Gross plant weight was highest (1.15 kg) for New Orient (T2) which was on par with NS-183 (T8-1.11 kg) and BC-38 (T9-1.02 kg) and lowest for T3, Gayatri (0.52 kg).

Interaction effect was also significant. November 1st sowing of NS-183 (D3T8) recorded maximum gross plant weight (1.33 kg) followed by D3T2 (New

Table 4. Effect of sowing dates, varieties and their interaction on plant height, non wrapper leaves per plant and gross plant weight of cabbage

Varieties	Plant height (cm)					Non wrapper leaves per plant					Gross plant weight (kg)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	22.67	24.74	22.82	24.68	23.72	17.73	18.46	18.13	18.46	18.19	1.06	1.21	0.99	0.87	1.03
T2	25.93	29.18	29.92	29.49	28.63	17.86	18.20	18.20	17.40	17.91	1.02	1.21	1.30	1.06	1.15
T3	16.93	15.47	19.82	16.02	17.06	16.73	16.06	17.26	16.53	16.64	0.46	0.59	0.59	0.45	0.52
T4	21.16	22.22	23.10	22.14	22.15	16.06	16.46	17.73	15.20	16.36	0.81	0.81	0.71	0.79	0.78
T5	24.53	23.69	24.92	24.28	24.35	18.93	15.06	16.8	15.40	16.54	0.98	0.91	0.92	0.82	0.90
T6	24.30	23.7	25.96	24.50	24.61	19.13	16.60	18.46	16.60	17.69	1.00	0.83	1.03	0.95	0.95
T7	18.32	20.16	21.33	19.13	19.735	16.53	16.40	15.73	15.40	16.01	0.63	0.89	0.85	1.08	0.86
T8	27.62	27.41	27.81	27.44	27.57	16.93	18.33	17.14	17.66	17.51	0.89	1.22	1.33	0.99	1.11
T9	22.93	23.90	26.44	24.32	24.39	19.53	18.00	20.40	18.20	19.03	0.75	1.21	1.24	0.89	1.02
T10	24.08	25.88	27.83	22.94	25.18	18.73	17.66	19.73	17.66	18.44	0.86	0.93	1.13	0.99	0.97
T11	28.84	30.79	33.74	29.62	30.75	19.93	18.00	19.73	19.00	19.16	0.87	0.94	0.97	0.73	0.87
Mean	23.39	24.28	25.79	24.05		18.00	17.20	18.11	17.04		0.84	0.98	1.00	0.87	
CD (5%)	D				1.88					0.25					0.07
	T				2.84					0.48					0.13
	DxT				5.69					0.96					0.26

Fig.1 Effect of sowing dates, varieties and their interaction on plant height of cabbage



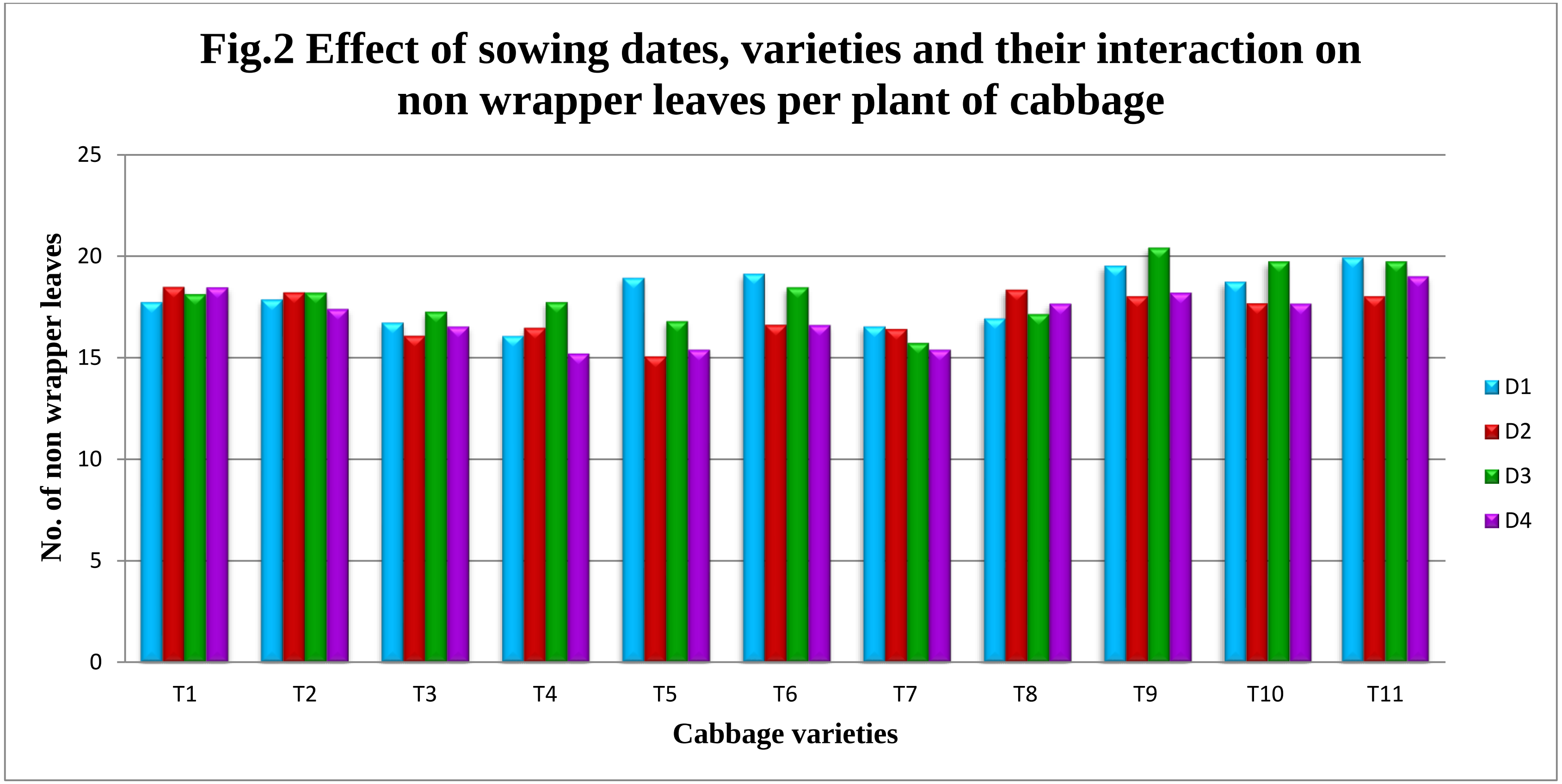
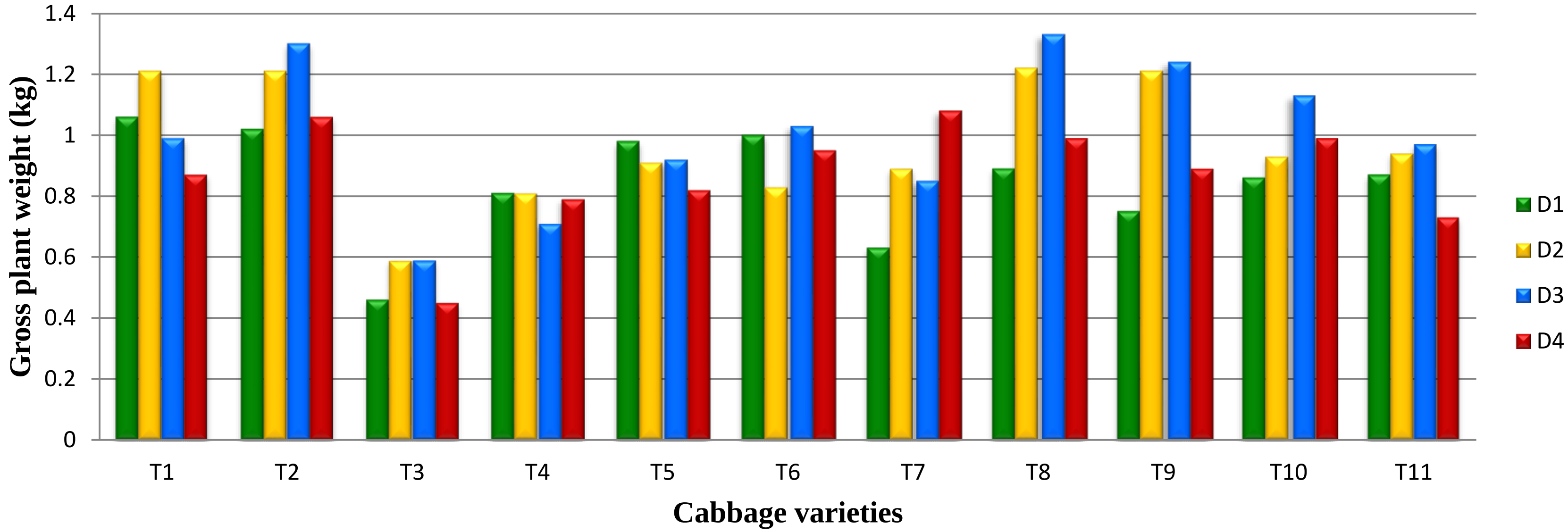


Fig.2 Effect of sowing dates, varieties and their interaction on non wrapper leaves per plant of cabbage
No. of non wrapper leaves
0
5
10
15
20
25
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
Cabbage varieties
D1
D2
D3
D4

Fig. 3 Effect of sowing dates, varieties and their interaction on gross plant weight of cabbage



Orient-1.30 kg). Minimum gross plant weight (0.45 kg) was recorded for Gayatri sown on November 15th (D4T3) (Fig. 3).

4.1.1.4 Leaf length

Leaf length was significantly influenced by different sowing dates (Table 5). November 1st sowing (D3) recorded maximum leaf length (26.23 cm) whereas October 1st sowing (D1) recorded the minimum (20.38 cm).

Significant difference was observed for varieties also. New Orient (T2) had the longest leaf (27.66 cm) which was on par with Red C-05 (27.05cm) and Indam Radha (25.61 cm). Minimum leaf length (16.90 cm) was recorded in Gayatri (T3).

D x T interaction was also significant. Maximum leaf length was observed in D3T2 (31.62 cm) which was on par with D3T11 (30.82 cm), D2T11 (30.66 cm) and D2T2 (29.36 cm). Minimum leaf length was recorded for D1T3 (13.56 cm) and D2T3 (14.06 cm).

4.1.1.5 Leaf breadth

Leaf breadth was significantly influenced by different sowing dates (Table 5). November 1st sowing (D3) recorded maximum leaf breadth (21.99 cm) followed by October 15th sowing (21.37 cm). October 1st sowing recorded the minimum leaf breadth (20.22 cm).

Significant difference was obtained for varieties also. Leaf breadth was highest (26.11 cm) for New Orient (T2) and lowest (15.43 cm) for Gayatri (T3).

Interaction between varieties and sowing dates influenced the leaf breadth significantly. Highest leaf breadth (28.67 cm) was observed for New Orient (T2) sown on November 15th (D4) which was on par with D3T2 the same sown on November 1st (27.98 cm). Lowest value was obtained for D1T3 (12.82 cm) which was on par with D2T3 (12.96 cm).

4.1.1.6 Leaf size

Leaf size was significantly influenced by date of sowing (Table 5). Highest leaf size (585.94 cm^2) was observed in November 1st sowing (D3) and lowest for October 1st sowing (D1) (406.98 cm^2).

Significant variation was obtained among different varieties also. New Orient (T2) was superior for leaf size (730.81 cm^2). Smallest leaf size (270.08 cm^2) was observed in Gayatri (T3).

Interaction between varieties and sowing dates influenced the leaf size of plants significantly. Highest leaf size (884.26 cm^2) was observed in New Orient sown on November 1st (D3T2). Smallest leaf size (174.39 cm^2) was observed in Gayatri sown on October 1st (D1T3) and October 15th (182.23 cm^2) respectively (Fig.4).

4.1.2 Head characters

4.1.2.1 Days to head formation

Days to head formation varied significantly for different sowing dates (Table 6). November 1st sowing (D3) resulted in earliest head formation (43.26 days) while on October 1st sowing (D1) resulted in latest (47.78 days).

Varietal difference also influenced days to head formation in cabbage. New Orient (T2) and NS- 183 (T8) were the earliest and took 42.04 and 42.44 days respectively. Red C-05 (T11) was latest (54.55 days) followed by Indam 296 (T5) (48.13 days).

Significant difference was observed between D x T interaction also. NS-183 (40.23 days) and New Orient (40.53 days) sown on November 1st (D3) resulted early head formation. Maximum days for head formation were observed in D1T11 (58 days) which was on par with D3T11 (57.17 days).

Table 5. Effect of sowing dates, varieties and their interaction on leaf length, leaf breadth and leaf size of cabbage

Varieties	Leaf length (cm)					Leaf breadth (cm)					Leaf size (cm^2)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	20.42	23.40	27.54	22.38	23.43	21.35	23.77	21.80	21.42	22.18	436.45	556.37	600.84	480.02	518.42
T2	21.94	29.36	31.62	27.73	27.66	22.24	25.55	27.98	28.67	26.11	488.83	751.52	884.26	798.62	730.81
T3	13.56	14.06	20.91	19.08	16.90	12.82	12.96	17.02	18.93	15.43	174.39	182.23	356.44	367.25	270.08
T4	19.49	20.12	23.16	19.97	20.68	18.80	15.26	21.61	17.89	18.48	367.00	308.08	499.78	358.04	383.23
T5	15.36	20.76	25.53	21.26	20.72	22.29	18.31	19.43	21.35	20.35	339.24	381.93	495.96	453.98	417.78
T6	27.39	24.78	25.79	24.50	25.61	17.97	21.04	22.95	21.95	20.98	366.75	521.46	591.92	538.76	504.72
T7	17.34	18.26	22.33	22.28	20.05	15.16	21.70	18.22	18.50	18.45	264.41	394.63	411.46	416.27	371.69
T8	20.85	24.14	28.72	21.04	23.69	21.52	24.82	23.28	21.11	22.73	448.93	599.48	669.43	447.44	541.32
T9	22.60	24.28	28.08	22.74	24.43	24.22	25.26	22.99	22.00	23.62	547.91	614.38	646.03	503.00	577.83
T10	22.93	14.62	24.07	22.42	21.01	24.33	23.94	22.71	20.95	22.98	558.98	557.13	550.56	470.27	534.24
T11	22.30	30.66	30.82	24.44	27.05	21.73	22.42	23.87	19.17	21.77	483.90	687.65	738.66	465.67	593.97
Mean	20.38	22.22	26.23	22.53		20.22	21.37	21.99	21.15		406.98	504.99	585.94	481.76	
CD (5%)	D				1.74					0.37					18.73
	T				2.21					0.95					41.44
	DxT				4.42					1.92					82.89

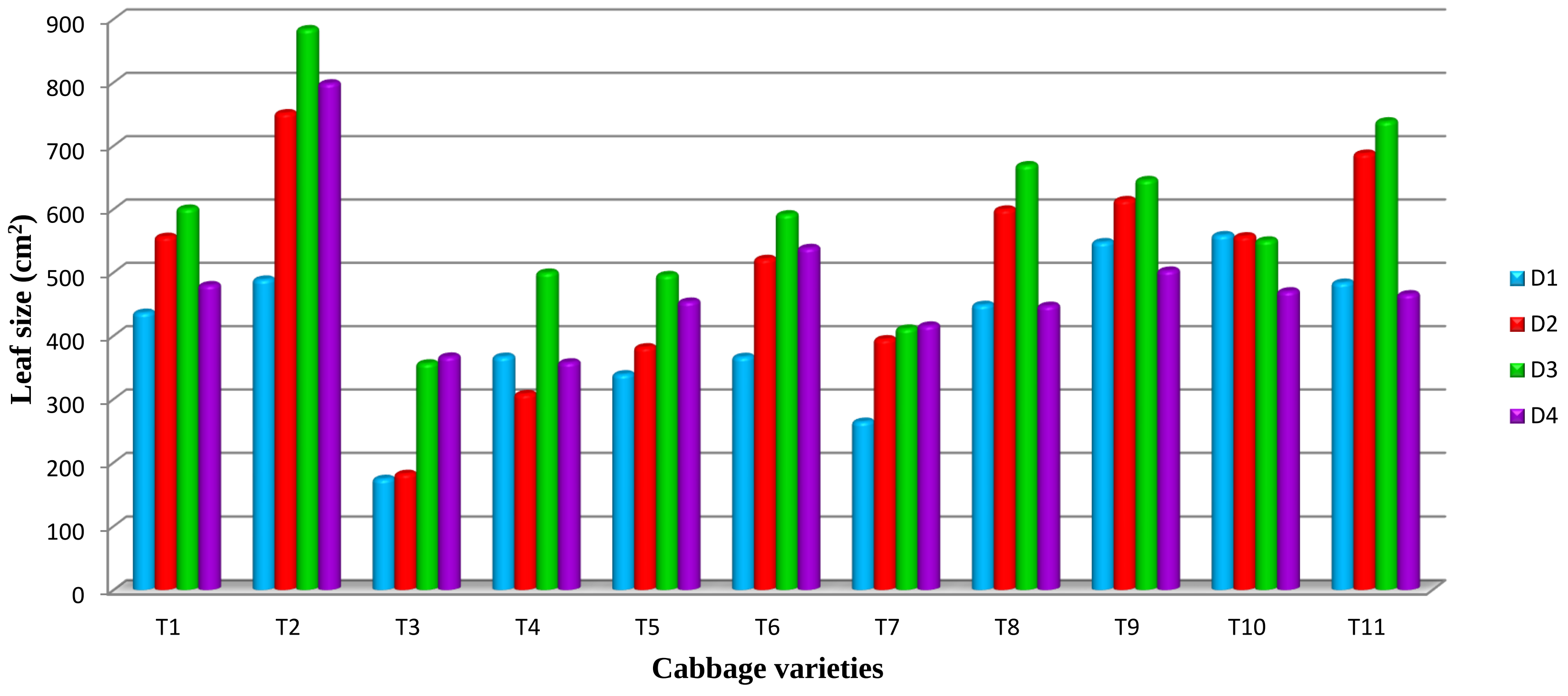


Fig.4 Effect of sowing dates, varieties and their interaction on leaf size of cabbage

4.1.2.2 Days to head harvest

Days to head harvest was significantly influenced by different sowing dates (Table 6). November 1st sowing (D3) resulted in minimum days to head harvest (72.56 days) which was on par with October 15th sowing (D2- 73.67 days). October 1st sowing (D1) resulted in maximum days to head harvest (75.20 days) which was on par with November 15th sowing (D4 - 74.69 days).

Varietal difference was also influenced by days to head harvest in cabbage. NS- 183 (T8) and New Orient (T2) were earliest and took 67.33 and 69.72 days respectively. Red C-05 (T11) was late for harvest (92.20 days).

Significant difference was observed between varieties and sowing dates. November 1st sowing of New Orient (D3T2) (64.20 days) and NS-183(D3T8) (64.40 days) recorded minimum days for head harvest. Maximum days for head harvest were recorded for Red C-05 in all the sowing dates (Fig.5).

4.1.2.3 Days to head maturity

Days to head maturity was significantly influenced by different sowing dates (Table 6). November 1st sowing (D3) resulted in minimum days for head maturity (73.78 days) while October 1st sowing (D1) resulted in maximum days (77.01 days).

Significant difference was observed among varieties for days to head maturity. Minimum days for head maturity was observed in T8, NS-183 (69.44 days) followed by T2, New Orient (71.61days). Maximum days taken for head maturity were observed in T11, Red C-05 (93.28 days).

Significant difference was observed between varieties and sowing dates. Minimum days for head maturity (66.53 days) were observed in NS-183 sown on November 1st (D3T8). Maximum days to head maturity were recorded for Red C-05 sown on October 1st (D1T11) (104.66 days).

Table 6. Effect of sowing dates, varieties and their interaction on days to head formation, days to head harvest and days to head maturity of cabbage

Varieties	Days to head formation					Days to head harvest					Days to head maturity				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	46.93	42.46	41.53	45.93	44.21	68.26	70.66	69.20	74.93	70.76	71.13	75.73	74.53	76.00	74.34
T2	44.00	40.73	40.53	42.93	42.04	73.40	69.00	64.20	72.46	69.72	73.53	71.46	70.46	71.00	71.61
T3	48.53	45.60	41.13	44.20	44.86	76.60	71.06	72.20	75.46	73.83	74.60	75.00	73.93	75.00	74.63
T4	46.13	44.80	42.40	44.53	44.47	73.20	73.00	70.06	75.46	72.93	73.60	75.80	73.40	76.20	74.75
T5	46.53	57.33	42.73	45.93	48.13	80.66	80.33	80.40	76.00	79.34	84.60	76.13	70.20	81.00	77.98
T6	47.88	47.40	43.93	47.27	46.62	77.10	77.33	78.40	76.00	77.21	73.06	76.80	74.00	77.03	75.22
T7	46.00	43.00	42.93	46.60	44.63	68.00	68.53	71.46	71.20	69.79	74.09	74.60	71.73	74.00	73.60
T8	44.40	41.26	40.23	43.87	42.44	65.60	66.00	64.40	73.33	67.33	68.66	71.66	66.53	70.93	69.44
T9	46.73	43.00	41.26	47.67	44.66	74.80	65.93	65.33	74.93	70.24	73.46	74.33	71.50	76.00	73.82
T10	50.46	42.60	42.01	46.53	45.40	74.66	68.80	67.73	72.80	70.99	75.66	69.66	70.33	74.40	72.51
T11	58.00	52.06	57.17	51.00	54.55	95.00	99.80	95.00	79.00	92.20	104.66	89.20	95.00	84.26	93.28
Mean	47.78	45.47	43.26	46.04		75.20	73.67	72.56	74.69		77.01	75.49	73.78	75.98	
CD (5%)	D				0.92					1.42					1.17
	T				0.87					1.68					1.66
	DxT				1.73					3.36					3.32

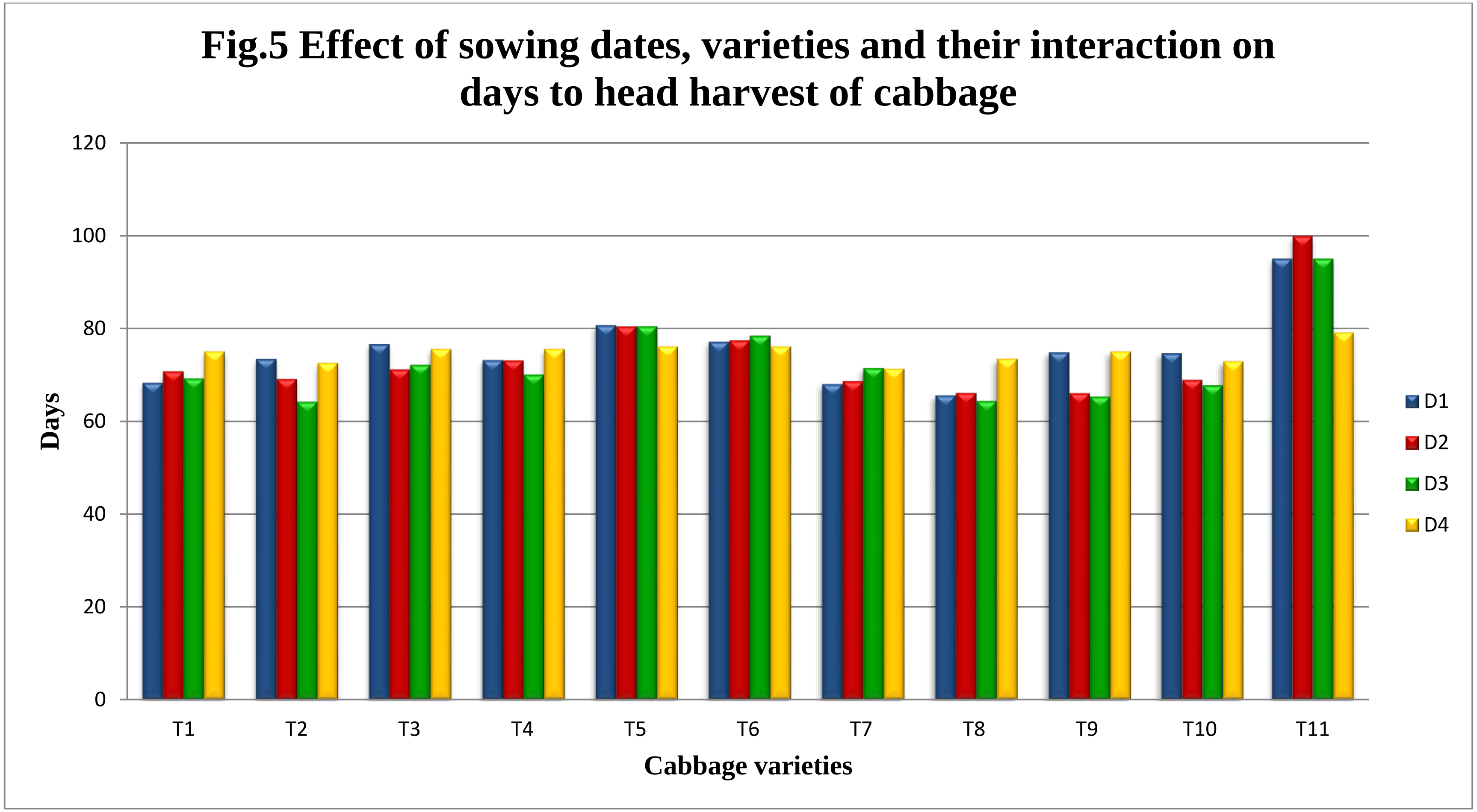


Fig.5 Effect of sowing dates, varieties and their interaction on days to head harvest of cabbage
Days
0
20
40
60
80
100
120
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
Cabbage varieties
D1
D2
D3
D4

4.1.2.4 Head depth

Head depth was significantly influenced by different sowing dates (Table 7). Maximum head depth (10.67 cm) was observed in November 1st sowing (D3) while minimum head depth (9.73 cm) in October 1st sowing (D1).

Significant differences were obtained for varieties also. Head depth was maximum for T8, NS-183 (11.88 cm) followed by T2, New Orient (11.49 cm) and lowest for T11, Red C-05 (9.21 cm).

Interaction effect was significant for head depth. Maximum head depth was observed for D3T2 (13.29 cm) which was on par with D3T8 (12.78 cm). Minimum head depth was observed for D4T11 (7.98 cm) which was on par with D1T10 (7.96 cm) (Fig.6).

4.1.2.5 Head diameter

Head diameter was significantly influenced by different sowing dates (Table 7). November 1st sowing (D3) recorded maximum head diameter (10.45 cm) while October 1st sowing (D1) recorded the minimum (8.98 cm).

Significant differences were obtained for varieties also. Highest head diameter (11.87cm) was observed in T2, New Orient which was on par with T8, NS-183 (11.86 cm), T10, Asia Cross (11.58 cm) and lowest for T3, Gayatri (6.78 cm).

Interaction effect was also significant for head diameter. Maximum head diameter (12.98 cm) was recorded for D3T2 which was on par with D3T8 (12.70 cm). Minimum head diameter (6.06 cm) was recorded for D1T3 which was on par with D4T3 (6.25 cm) (Fig.7).

4.1.2.6 Head solidity

Head solidity was not significantly influenced by different sowing dates (Table 8). But significant difference was observed among varieties. Highest head solidity (55.53 g/cm^3) was observed in T11, Red C-05 followed by T8, NS-183 (46.20

Table 7. Effect of sowing dates, varieties and their interaction on head depth and head diameter of cabbage

Varieties	Head depth (cm)					Head diameter (cm)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	11.06	10.29	9.46	7.50	9.5	11.66	11.82	12.17	8.9	11.13
T2	10.10	11.02	13.29	11.56	11.49	10.98	12.62	12.98	10.91	11.87
T3	8.93	9.82	10.64	9.13	9.63	6.06	7.7	7.12	6.25	6.78
T4	10.42	9.62	10.67	11.00	10.42	7.55	7.97	8.16	7.88	7.89
T5	9.71	10.40	10.22	10.66	10.24	9.06	8.21	9.8	8.76	8.96
T6	9.46	9.42	9.37	9.93	9.54	8.32	7.95	11.58	8.75	9.15
T7	10.46	10.72	11.42	11.74	11.08	6.59	7.88	10.62	9.66	8.68
T8	11.19	11.58	12.78	11.96	11.88	9.44	12.49	12.7	12.81	11.86
T9	8.50	9.56	9.48	9.79	9.33	11.9	12.7	11.3	9.19	11.27
T10	7.96	9.05	9.98	8.51	8.87	11.14	12.79	10.42	11.98	11.58
T11	9.27	9.50	10.09	7.98	9.21	6.14	7.43	8.18	6.14	6.97
Mean	9.73	10.08	10.67	9.97		8.98	9.96	10.45	9.20	
CD (5%)	D				0.37					0.24
	T				0.47					0.58
	DxT				0.95					1.20

Fig.6 Effect of sowing dates, varieties and their interaction on head depth of cabbage

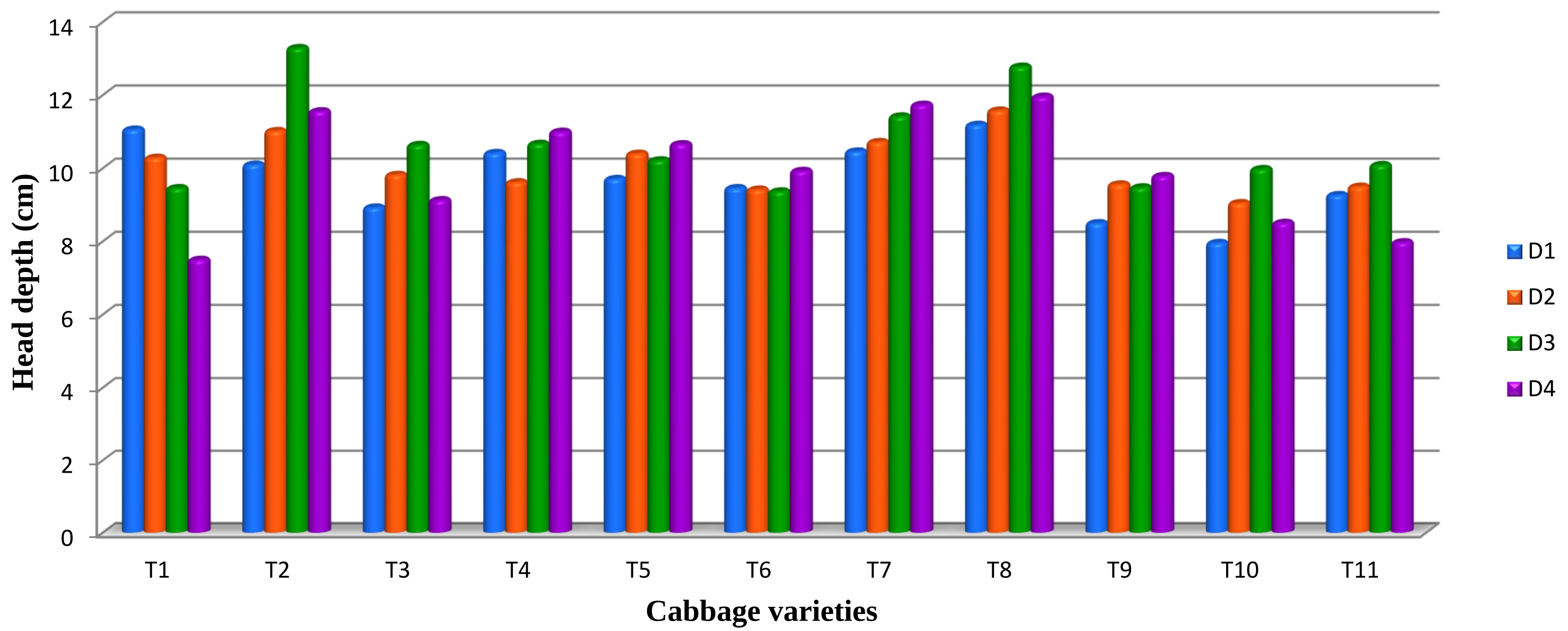


Fig.7 Effect of sowing dates, varieties and their interaction on head diameter of cabbage

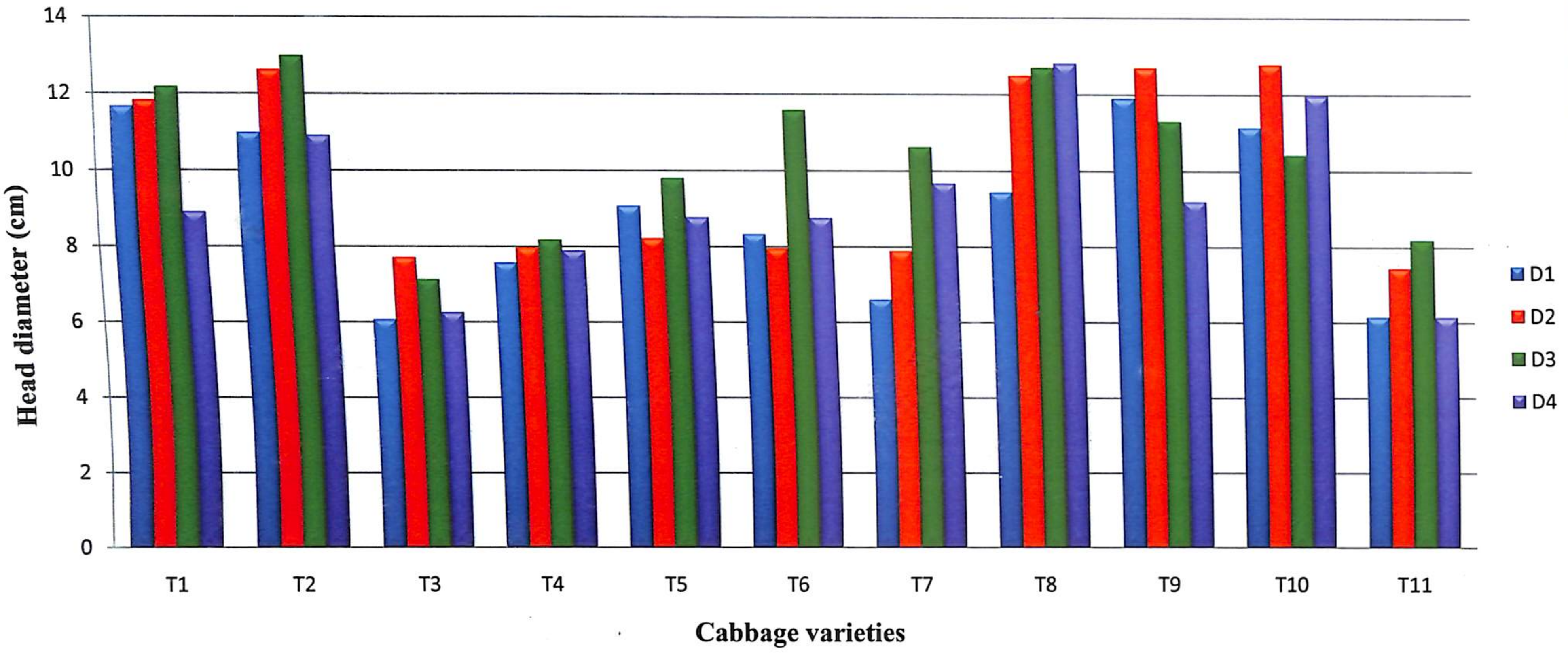
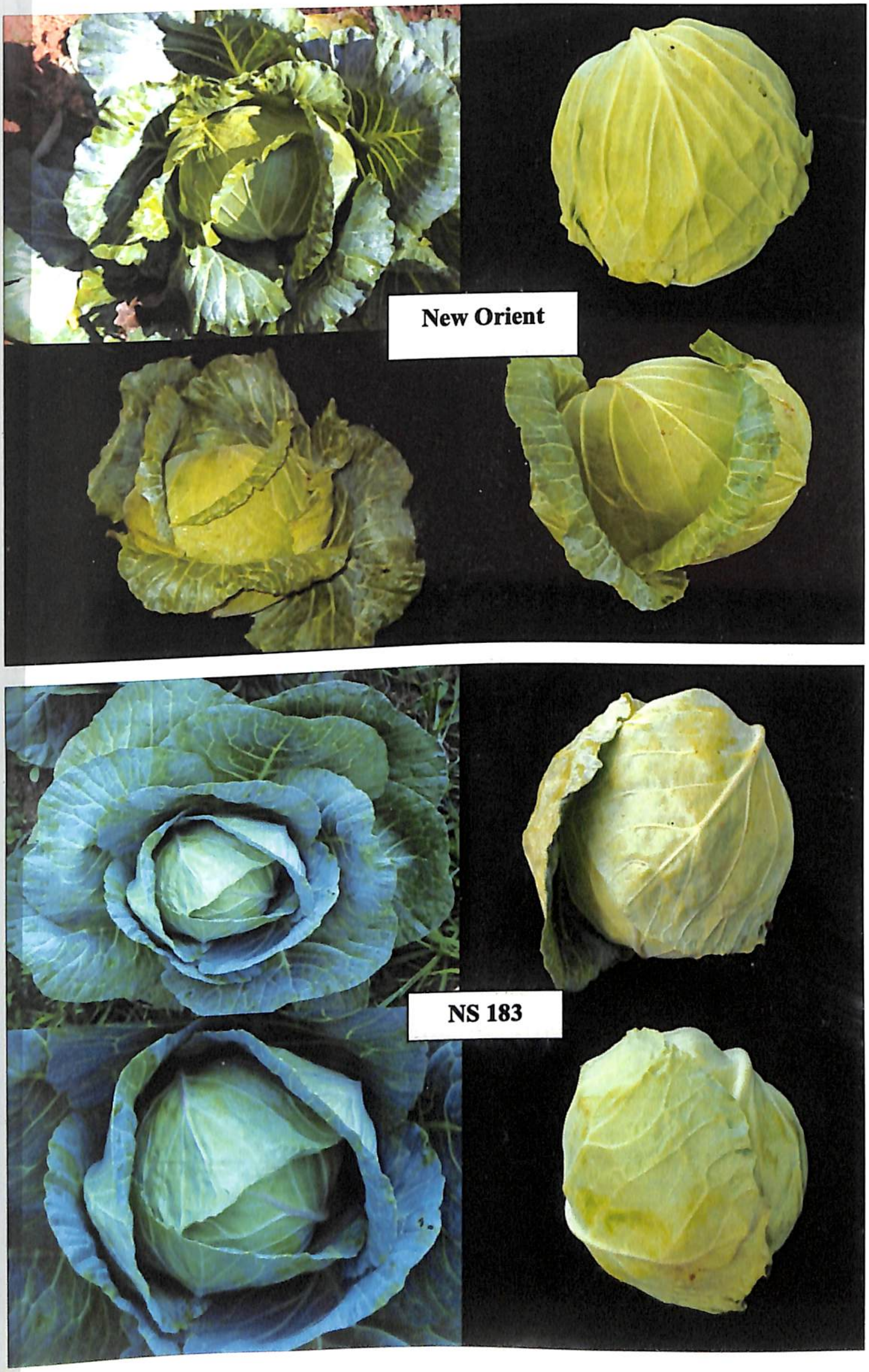


Plate 5. Top yielders



g/cm^3). Lowest value for head solidity was observed in T1, Summer Cross (36.69 g/cm^3).

Interaction effect was significant for head solidity. Maximum head solidity was observed for D3T11 (65.98 g/cm^3) which was on par with D2T11 (54.42 g/cm^3) and D1T11 (52.89 g/cm^3). D1T1 had minimum head solidity (24.74 g/cm^3) which was on par with D3T6 (32.59 g/cm^3), D1T10 (34.29 g/cm^3) and D2T10 (34.86 g/cm^3).

4.1.2.7 Core length

Core length was not significantly influenced by different dates of sowing (Table 8). But it was significantly influenced by different varieties. Lowest core length (5.14 cm) were observed in Veer-333 (T4) and Indam Radha (T6) which was on par with T10 (5.18 cm), T3 (5.25 cm), T9 (5.33 cm), T5 (5.48cm), T2 (5.89 cm) and T8 (5.89 cm). Core length was highest for Red C-05 (T11 -6.88 cm) followed by T7 (6.28 cm) and T1 (6.29 cm).

D x T interaction significantly influenced core length of head. Lowest core length was observed in D3T6 (4.82 cm) which was on par with D3T4 (4.84 cm), D2T4 (4.84 cm), D4T3 (4.84 cm), D1T4 (4.96 cm) and D4T5 (4.96 cm). Maximum core length (7.18 cm) was recorded for Red C 05 planted during October 15th (D2T11) which was on par with D4T11 (7.14 cm) and D1T11 (6.62 cm).

4.1.3 Yield characters

4.1.3.1 Net head weight

Net head weight was significantly influenced by different sowing dates and varieties (Table 9). Maximum net head weight (519.03 g) was recorded by November 1st sowing (D3) followed by October 15th sowing (451.21g). October 1st sowing recorded minimum net head weight (306.13 g). Among varieties, highest net head weight was observed for T2, New Orient (645 g) which was on par with T8, NS-183 (614.83 g). Gayatri (T3) recorded lowest net head (weight(217.17 g).

Table 8. Effect of sowing dates, varieties and their interaction on head solidity and core length of cabbage

Varieties	Head solidity (g/cm^3)					Core length (cm)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	24.74	41.94	38.10	41.99	36.69	6.20	6.12	6.27	6.60	6.29
T2	38.94	38.12	44.04	41.77	40.72	5.67	5.98	5.92	6.02	5.89
T3	42.75	38.86	45.32	41.15	42.02	5.96	5.11	5.11	4.84	5.25
T4	36.86	43.68	46.09	44.30	42.73	4.96	4.84	4.84	5.94	5.14
T5	44.44	43.19	40.48	41.22	42.33	5.27	6.58	5.14	4.96	5.48
T6	45.55	47.93	32.59	44.97	42.76	5.12	5.56	4.82	5.09	5.14
T7	40.67	44.26	40.00	37.00	40.48	6.52	6.48	5.75	6.38	6.28
T8	48.28	46.71	49.17	40.65	46.20	5.74	5.81	5.99	6.02	5.89
T9	37.52	40.81	44.36	40.69	40.85	4.88	5.63	5.39	5.42	5.33
T10	34.29	34.86	48.29	41.78	39.81	5.06	5.22	5.27	5.19	5.18
T11	52.89	54.42	65.98	48.84	55.53	6.62	7.18	6.58	7.14	6.88
Mean	40.63	43.16	44.95	42.21		5.63	5.86	5.55	5.78	
CD (5%)	D				7.98					0.54
	T				8.05					0.78
	DxT				13.10					1.24

Significant difference was observed between varieties and sowing dates. New Orient sown on November 1st (D3T2) recorded maximum net head weight (876.67g) followed by NS-183 sown on November 1st (D3T8 - 851.33g). It was minimum for D1T3 (180.00 g) which was on par with D2T3 (194.00 g) (Fig. 8).

4.1.3.2 Gross head weight

Gross head weight was significantly influenced by different sowing dates and varieties (Table 9). Maximum gross head weight (559.12 g) was observed in November 1st sowing and minimum for October 1st sowing (330.39 g).

Varietal difference was also significant. Maximum gross head weight (682.50 g) was observed in New Orient (T2) which was on par with T8, NS-183 (638.83g). Lowest gross head weight (241.42 g) was observed in Gayatri (T3).

Significant difference was observed between varieties and sowing dates. Maximum gross head weight (922.67 g) was recorded for D3T2 which was on par with D3T8 (884.33 g). Minimum gross head weight was recorded for D1T3 (200.00 g) which was on par with and D2T3 (200.00 g).

4.1.3.3 Harvest index

Harvest index was significantly influenced by different sowing dates and varieties (Table 10). Harvest index was maximum (0.50) for November 1st sowing. Lowest harvest index was observed in October 1st sowing (0.36).

Among varieties, highest harvest index (0.55) was observed in T2, New Orient which was on par with T8, NS-183 (0.53). Lowest harvest index was observed in T11, Red C-05 (0.32).

Interaction effect was significant for harvest index. Maximum harvest index was recorded for D3T2 (0.67) which was on par with D3T8 (0.64), D2T8 (0.62) and D2T2 (0.61). Minimum harvest index was recorded for D4T11 (0.31) which was on par with D2T3 (0.32) (Fig 9).

Table 9. Effect of sowing dates, varieties and their interaction on net head weight and gross head weight of cabbage

Varieties	Net head weight (g)					Gross head weight (g)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	362.67	566.66	552.00	325.33	451.66	380.67	598.66	592.00	355.33	481.66
T2	456.00	740.00	876.67	507.33	645.00	490.00	780.00	922.67	537.33	682.50
T3	180.00	194.00	229.33	205.33	202.16	200.00	200.00	320.33	245.33	241.42
T4	267.34	338.00	384.67	372.67	340.67	290.34	400.00	410.67	400.67	375.42
T5	367.33	348.00	406.00	377.33	374.66	398.33	368.00	450.00	430.33	411.66
T6	320.00	314.00	374.67	382.67	347.83	350.00	350.00	400.67	440.67	385.33
T7	252.00	356.00	354.00	562.00	381.00	283.00	370.00	380.00	590.00	405.75
T8	343.33	762.00	851.33	502.67	614.83	358.33	770.00	884.33	542.67	638.83
T9	292.00	562.67	710.67	382.00	486.83	315.00	574.67	760.67	450.00	525.09
T10	298.67	454.00	618.67	449.33	455.16	320.67	467.00	648.67	490.33	481.67
T11	228.11	328.00	351.33	226.33	283.44	248.00	350.00	380.33	240.00	304.58
Mean	306.13	451.21	519.03	390.27		330.39	475.30	559.12	429.33	
CD (5%)	D				20.46					24.90
	T				44.45					47.35
	DxT				89.04					94.71

4.1.3.4 Yield per plot

Yield per plot was significantly influenced by different sowing dates and varieties (Table 10). November 1st sowing (D3) recorded maximum plot yield (12.98 kg) while October 1st sowing (D1) recorded the minimum (7.65 kg).

Highest yield per plot (16.13 kg) was recorded for New Orient (T2) which was on par with NS-183 (T8 - 15.37 kg). Lowest yield per plot (5.42 kg) was recorded for Gayatri (T3).

Significant difference was observed between varieties and sowing dates. Maximum yield per plot was obtained for D3T2 (21.91 kg) which was on par with D3T8 (21.28 kg). Minimum yield per plot (4.50 kg) was recorded for D1T3 which was on par with D2T3 (4.85 kg).

4.1.4 Quality characters

4.1.4.1 Protein

Protein content was not significantly influenced by different sowing dates (Table 11). But it was significant for different varieties. Highest protein (1.12%) content was recorded in Red C-05 (T11) which was on par with T8 (1.06%) and T7 (1.05 %). Lowest protein content was recorded for Veer- 333 (T4 - 0.98%) which was on par with Asia cross (T10 - 0.99%).

Significant difference was observed between varieties and sowing dates. Maximum protein content was recorded for Red C-05 in all the planting dates. Minimum protein content was recorded for D2T4 (0.95%), D4T10 (0.98%), D2T3 (0.99%), D4T3 (0.99%), D1T4 (0.99%), D4T4 (0.99%), D2T6 (0.99%), D2T10 (0.99%) and D3T10 (0.99%).

4.1.4.2 Vitamin A (IU)

Vitamin A was not significantly influenced by different sowing dates (Table 11). But significant variation was observed among different varieties. Vitamin A was highest (649.63 IU) for New Orient (T2) followed by T9 (602.94 IU) which was on par with T8 (569.17 IU) and least for T1 (400.15 IU).

Table 10. Effect of sowing dates, varieties and their interaction on harvest index and yield per plot of cabbage

Varieties	Harvest Index					Yield per plot (kg)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	0.34	0.46	0.55	0.37	0.43	9.06	14.16	13.80	8.13	11.29
T2	0.44	0.61	0.67	0.47	0.55	11.40	18.50	21.91	12.68	16.13
T3	0.39	0.32	0.38	0.45	0.39	4.50	4.85	7.23	5.13	5.42
T4	0.33	0.41	0.54	0.47	0.44	6.68	8.45	9.61	9.31	8.51
T5	0.37	0.38	0.44	0.46	0.41	9.18	8.70	10.15	9.43	9.36
T6	0.32	0.37	0.36	0.40	0.36	8.00	7.85	9.36	9.56	8.69
T7	0.40	0.40	0.41	0.52	0.43	6.30	8.90	8.85	14.05	9.52
T8	0.39	0.62	0.64	0.51	0.53	8.58	19.05	21.28	12.56	15.37
T9	0.38	0.46	0.57	0.42	0.46	7.30	14.06	17.76	9.55	12.17
T10	0.34	0.48	0.54	0.45	0.45	7.46	11.35	15.46	11.23	11.37
T11	0.26	0.34	0.36	0.31	0.32	5.70	8.20	8.78	5.66	7.08
Mean	0.36	0.44	0.50	0.44		7.65	11.28	12.98	9.76	
CD (5%)	D				0.03					0.49
	T				0.07					1.10
	DxT				0.09					2.20

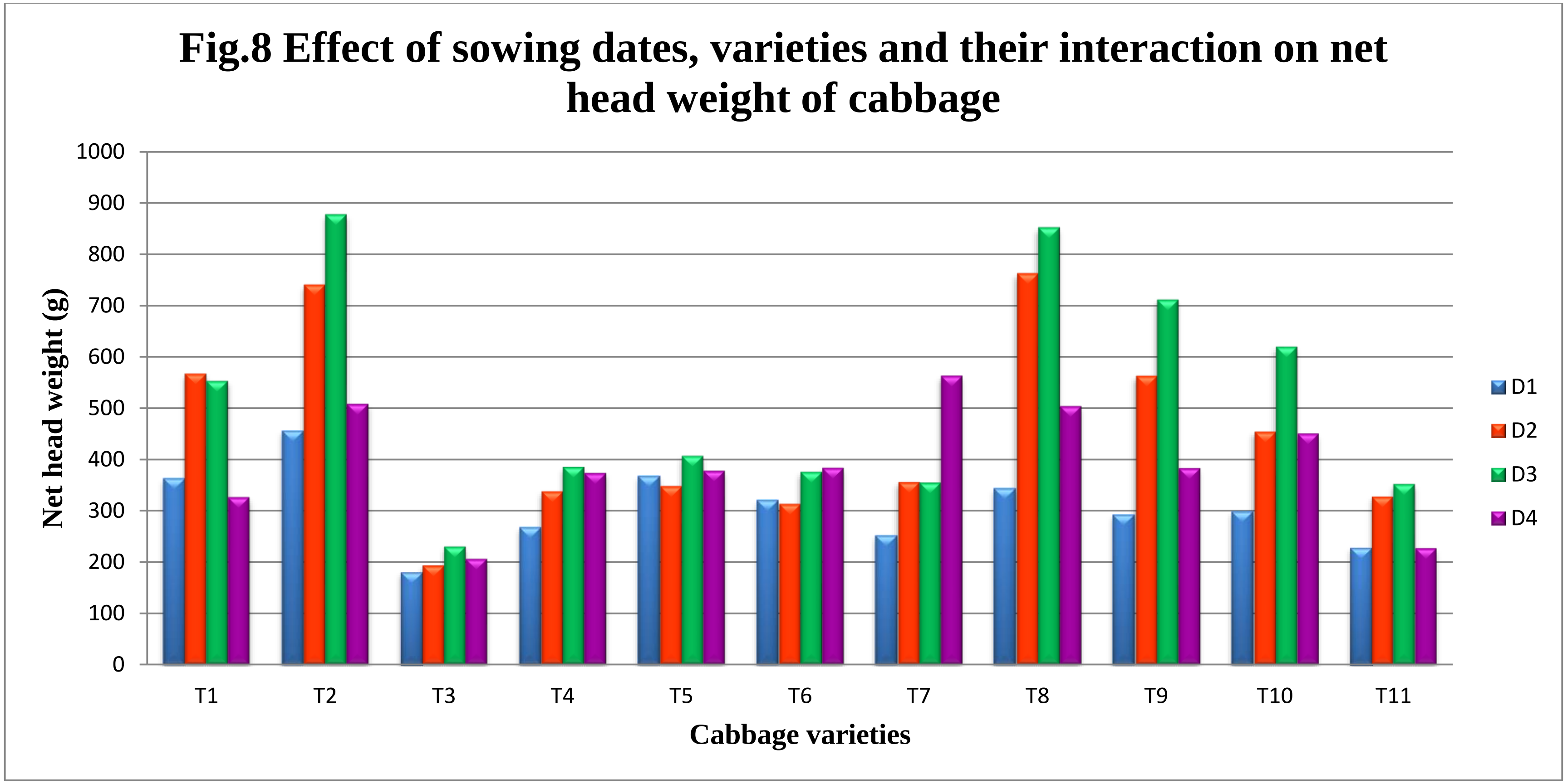


Fig.8 Effect of sowing dates, varieties and their interaction on net head weight of cabbage
Net head weight (g)
1000
900
800
700
600
500
400
300
200
100
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
Cabbage varieties
D1
D2
D3
D4

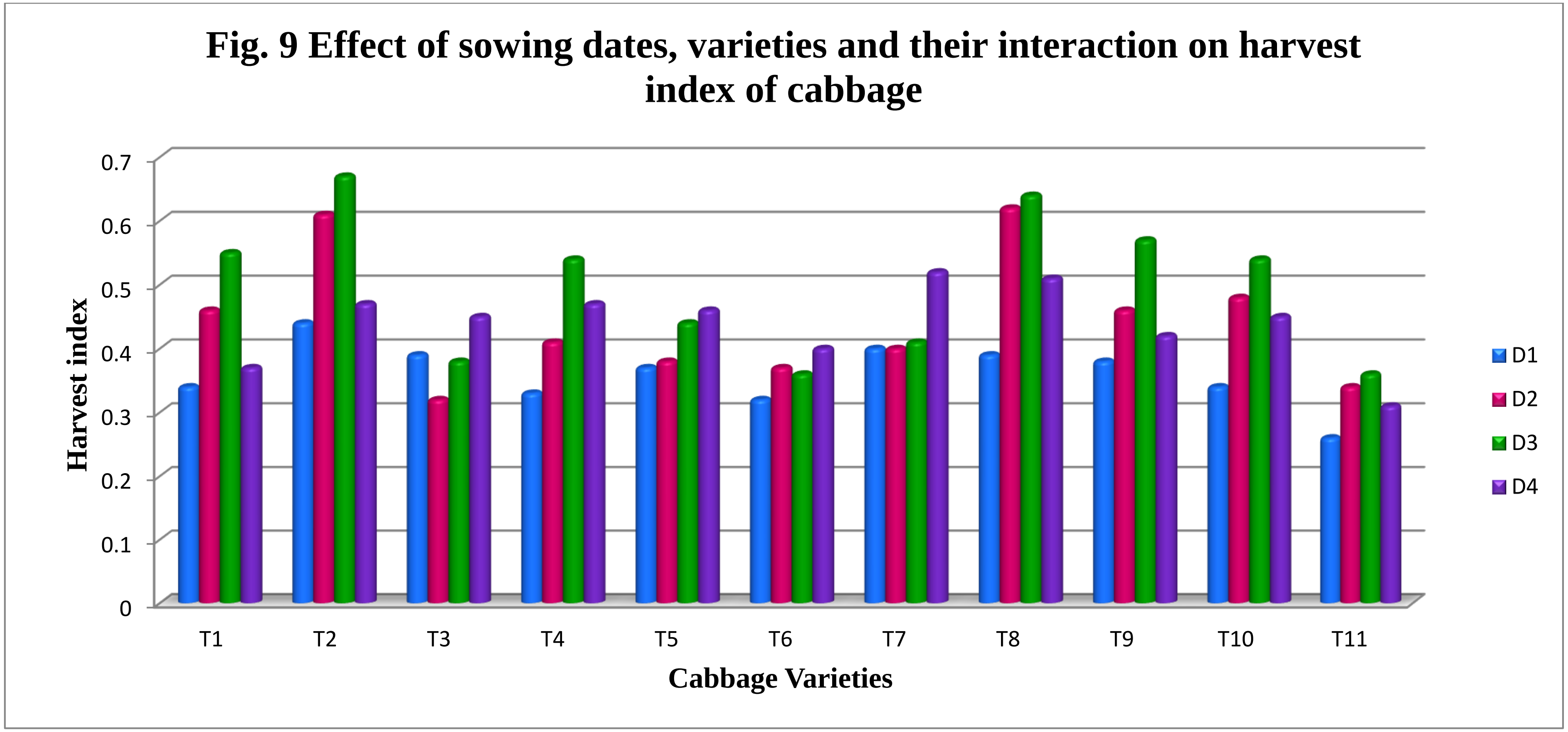


Fig. 9 Effect of sowing dates, varieties and their interaction on harvest index of cabbage
Harvest index
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
Cabbage Varieties
D1
D2
D3
D4

Significant differences were observed between varieties and sowing dates. Maximum Vitamin A was observed in D3T2 (652.21 IU) which was on par with D1T2 (649.10 IU), D4T2 (649.10 IU) and D2T2 (648.11 IU). Minimum vitamin A was recorded for D2T1 (399.10 IU) which was on par with D4T1 (399.10 IU), D1T1 (400.10 IU), D3T1 (402.30 IU) and D1T3 (423.21 IU).

4.1.4.2 Vitamin C (mg/100g)

Vitamin C content was not significantly influenced by different sowing dates (Table 11). Significant difference was observed for different varieties. Vitamin C content was highest for Red C- 05 (T11- 70.97 mg/100g). Lowest vitamin C content was recorded for T7 (19.19 mg/100g).Interaction between varieties and sowing dates influenced vitamin C content significantly. Maximum vitamin C content was observed in D3T11 (75.23 mg/100g) which recorded higher vitamin C content in all the sowing dates. Lowest value (18.23 mg/100g) was observed for Indam 1299 sown on October 15th (D2T7).

4.1.5 Morphological characters

Morphological characters like position of leaf, head shape, seedling leaf colour, seedling leaf margin serration, shape of leaf blade, leaf colour, leaf waxiness, undulation of leaf margin, head length, head diameter etc were recorded (Table 12). The varieties New Orient, Summer Cross, BC-38 and Asia Cross were exhibited semi erect type leaves and all the others had erect type leaves. Varieties Summer Cross, New Orient, BC- 38 and Asia Cross had flat heads while NS 183 and Indam 296 had round heads and Gayatri, Veer- 333 and Red C- 05 had elliptical head.

4.1.6 Incidence of physiological disorders

4.1.6.1 Burst head

Incidence of burst head was observed only in October 1st sowing (D1- 1.82 %) and November 15th sowing (D4 - 2.18 %) (Table 13).

Table 11. Effect of sowing dates, varieties and their interaction on quality characters of cabbage

Varieties	Protein (%)					Vitamin A (IU)					Vitamin C (mg)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	1.02	1.11	1.12	1.00	1.06	400.10	399.10	402.30	399.10	400.15	30.32	30.45	31.67	32.12	31.14
T2	1.01	1.01	1.02	1.03	1.01	649.10	648.11	652.21	649.10	649.63	32.12	32.91	33.69	34.23	33.23
T3	1.00	0.99	1.05	0.99	1.01	423.21	426.31	427.54	422.22	424.82	28.45	28.45	29.96	28.12	28.74
T4	0.99	0.95	1.00	0.99	0.98	499.32	500.11	508.13	501.55	502.28	21.11	22.11	22.72	20.98	21.73
T5	1.01	1.01	1.06	1.01	1.02	439.11	442.10	446.34	443.33	442.72	22.12	23.23	24.07	24.10	23.38
T6	1.04	0.99	1.07	1.03	1.03	509.33	511.17	515.83	512.43	512.19	30.22	32.11	33.45	33.11	32.22
T7	1.03	1.05	1.08	1.04	1.05	430.55	432.21	435.67	432.11	432.63	20.11	18.23	19.34	19.11	19.19
T8	1.05	1.07	1.06	1.06	1.06	568.22	569.99	570.13	568.36	569.17	34.23	36.44	35.46	37.23	35.84
T9	1.03	1.00	1.04	1.00	1.01	600.20	603.10	607.24	601.22	602.94	37.11	37.47	38.39	37.45	37.61
T10	1.00	0.99	0.99	0.98	0.99	499.00	498.55	501.09	499.11	499.43	36.23	36.99	38.33	37.99	37.38
T11	1.10	1.12	1.15	1.11	1.12	465.11	465.13	467.70	462.23	465.04	68.34	69.11	75.23	71.23	70.97
Mean	1.03	1.03	1.05	1.02		498.47	499.62	503.11	499.16		32.76	33.40	34.75	34.15	
CD (5%)	D				0.04					4.63					5.9
	T				0.06					36.34					18.81
	DxT				0.21					50.58					37.06

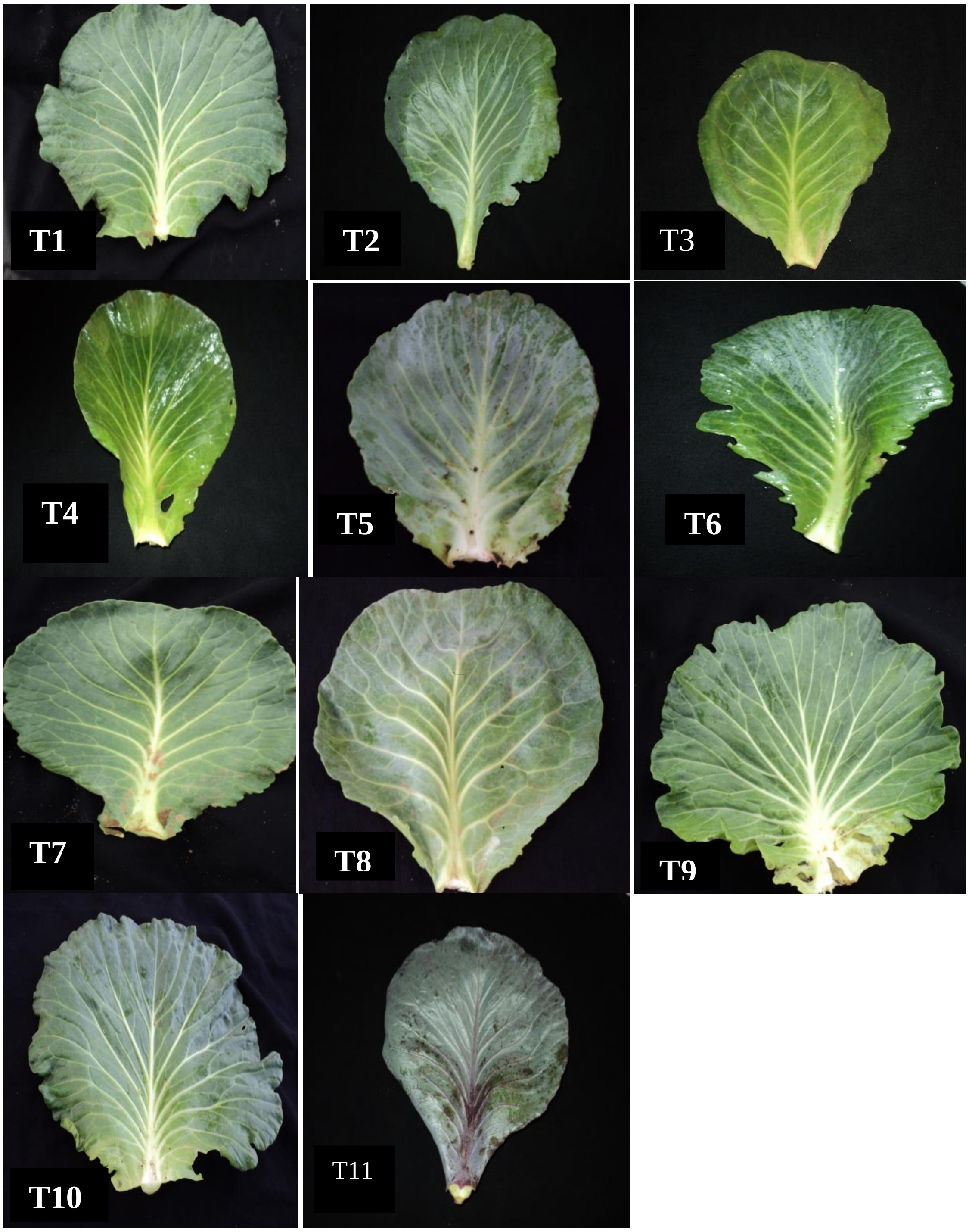


Plate 2. Variation in leaf shape and colour in different varieties of cabbage

T7

T8

T9

T10

T11

Plate 3b. Head characters of different varieties of cabbage

T1

T2

T3

T4

T5

T6

Plate 3b. Head characters of different varieties of cabbage

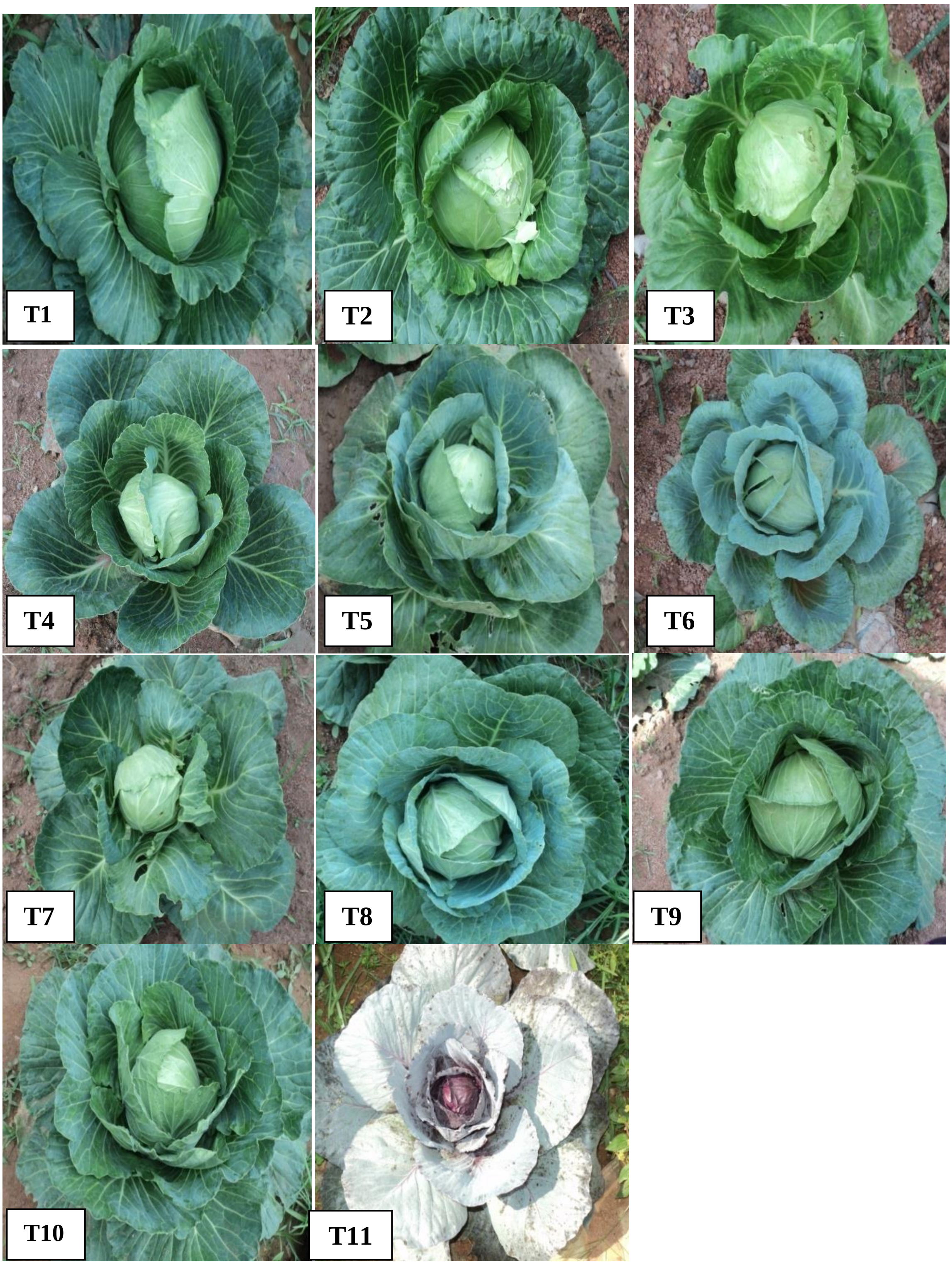


Plate 3a. Plant characters of different varieties of cabbage

Table 12. Morphological characters of 11 varieties in cabbage

Varieties	Seedling leaf colour	Seedling leaf margin serration	Position of leaves	Shape of leaf blade	Leaf colour	Leaf waxiness
T1	White green	Crenate	Semi-erect	Transverse broad elliptic	Green	Medium
T2	White green	Crenate	Semi-erect	Transverse broad elliptic	Green	Weak
T3	Dark green	No serration	Erect	Broad ovate	Green	Very weak
T4	White green	Crenate	Erect	Obovate	Whitish green	Medium
T5	White green	Crenate	Erect	Broad ovate	Whitish green	Strong
T6	Purple green	No serration	Erect	Obovate	Whitish green	Strong
T7	White green	Crenate	Erect	Obovate	Green	Medium
T8	White green	Crenate	Erect	Obvate	Whitish green	Strong
T9	White green	Crenate	Semi-erect	Transverse broad elliptic	Green	Medium
T10	White green	Crenate	Semi-erect	Transverse broad elliptic	Green	Medium
T11	Purple	Crenate	Erect	Obvate	Purple	Very strong

Varieties	Undulation of leaf margin	Shape of head	Shape of head in longitudinal section	Shape of head base in longitudinal section	Head length	Head diameter
T1	Medium	Flat	Transverse narrow elliptic	Flat	Medium	Medium
T2	Strong	Flat	Transverse elliptic	Flat	Medium	Large
T3	Weak	Elliptical	Broad elliptic	Round	Short	Small
T4	Weak	Elliptical	Broad elliptic	Round	Short	Small
T5	Very weak	Round	Broad elliptic	Round	Short	Small
T6	Medium	Obovate	Broad obovate	Round	Medium	Medium
T7	Weak	Elliptical	Broad elliptic	Round	Short	Small
T8	Weak	Round	Broad obovate	Round	Long	Large
T9	Medium	Flat	Transverse elliptic	Flat	Medium	Medium
T10	Medium	Flat	Transverse elliptic	Flat	Medium	Medium
T11	Medium	Elliptical	Broad elliptic	Round	Short	Small

Varieties	Head : position of maximum diameter	Head cover	Head anthocyanin colouration	Head internal colour	Head density	Head internal structure
T1	At middle	Covered	Very weak	Whitish	Medium	Coarse
T2	At middle	Covered	Very weak	Yellowish	Dense	Medium
T3	At middle	Covered	Very weak	Whitish	Dense	Medium
T4	Towards top	Covered	Very weak	Whitish	Dense	Medium
T5	At middle	Covered	Weak	Whitish	Dense	Medium
T6	Towards top	Partially covered	Weak	Yellowish	Dense	Medium
T7	At middle	Covered	Very weak	Whitish	Dense	Medium
T8	At middle	Covered	Weak	Whitish	Dense	Medium
T9	At middle	Covered	Very weak	Yellowish	Medium	Coarse
T10	At middle	Covered	Very weak	Yellowish	Medium	Coarse
T11	At middle	Covered	Very strong	Violet	Dense	Medium

Plate 4a .Physiological Disorder

Multiple head

Burst head

Plate 4b. Pest and Diseases

Leaf caterpillar

Alternaria leafspot

Rhizoctonia blight

Head rot

Among varieties, incidence of burst head was observed only in Gayatri (T3 - 4.00 %), Summer Cross (T1 - 2.00 %), Indam 1299 (T7 - 2.00 %), Asia Cross (T10 - 2.00 %) and BC-38 (T9 - 1.00 %).

Interaction effect varied significantly and incidence of burst head was observed in D4T3 (12.00 %), D1T1 (8.00 %), D1T3 (4.00%), D1T10 (8.00 %), D4T7 (8.00 %) and D4T9 (4.00 %).

4.1.6.2 Multiple head / Blindness

Incidence of multiple head was observed only in October 15th sowing (D2 - 1.64 %) and October 1st (D1 - 0.55 %) sowing. Among varieties, incidence of multiple head was observed only in BC – 38 (T9 - 3.50 %) and Summer Cross (T1- 2.50 %) (Table 13).

Interaction effect was observed only in D2T9 (10.00 %), D2T1 (8.00 %), D1T9 (4.00 %) and D1T1 (2.00 %).

4.1.7 Incidence of pest and diseases

4.1.7.1 Leaf caterpillar *(Spodoptera litura*)

Incidence of leaf caterpillar was significantly influenced by different sowing dates and varieties. Low incidence of leaf caterpillar was found in all dates of sowing. Lowest incidence (8.09 %) was observed in November 1st sowing (D3). Highest leaf caterpillar incidence (16.81 %) was observed for November 15th (D4) which was on par with October 1st sowing (D1 - 14.12 %) (Table 14)

Among different varieties, least incidence was recorded in NS – 183 (T8 - 8.25 %) which was on par with New Orient (T2 - 8.50%), T5 (9.75%). Highest incidence was observed in BC- 38 (T9 - 21.10 %) which was on par with Summer Cross (T1 - 21.00 %).

Interaction effect varied significantly and incidence of leaf caterpillar was maximum recorded for D4T1 (26.00%) which was on par with D1T9 (24.40%),

Table 13. Effect of sowing dates, varieties and their interaction on physiological disorders of cabbage

Varieties	Burst head (%)					Multiple head (%)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	8.00	0.00	0.00	0.00	2.00	2.00	8.00	0.00	0.00	2.50
T2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T3	4.00	0.00	0.00	12.00	4.00	0.00	0.00	0.00	0.00	0.00
T4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T7	0.00	0.00	0.00	8.00	2.00	0.00	0.00	0.00	0.00	0.00
T8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T9	0.00	0.00	0.00	4.00	1.00	4.00	10.00	0.00	0.00	3.50
T10	8.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
T11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	1.82	0.00	0.00	2.18		0.55	1.64	0.00	0.00	
CD (5%)	D				1.04					0.82
	T				2.42					1.83
	DxT				4.85					3.67

D2T9 (24.00%) and D4T6 (24.00%). Low incidence was observed in D3T5 (2.00%), D3T11 (4.00%), D2T11 (4.00%), D3T8 (6.00%), D3T2 (6.00%) and D3T7 (6.00%).

4.1.7.2 Alternaria leaf spot (*Alternaria brassicae*)

Incidence of alternaria leaf spot varied significantly among different sowing dates, varieties and their interactions (Table 14). Lowest incidence was noticed in November 1^{st} sowing (2.90 %) which was on par with October 15^{th} sowing (4.36 %) and November 15^{th} sowing (4.72 %). Incidence of alternaria leaf spot was found highest (14.45 %) for October 1^{st} sowing. Incidence of alternaria leaf spot was low (4.00 %) for T8 which was on par with T2 (4.00 %). High incidence (9.50 %) was observed in T9 which was on par with T1 (9.25 per cent), T10 (9.00 %), T6 (8.50 %) and T3 (6.50 %).

Least incidence (2.00 %) was noticed in D2T2 D2T8, D3T2, D3T4, D3T7, D3T8, D3T1, D3T11, D4T8 and D4T2. Highest incidence of alternaria leaf spot was recorded for D1T9 (22.00 %) which was on par with D1T1 (21.00 %) and D1T10 (20.00 %).

4.1.7.3 Rhizoctonia blight (*Rhizoctonia solani*)

Incidence of rhizoctonia blight varied significantly among different sowing dates, varieties and their interactions (Table 15). Lowest incidence (1.45 %) was recorded for November 1^{st} sowing (D3). It was found highest (22.29 %) for October 1^{st} sowing (D1).

Among varieties lowest incidence was recorded for T8, T2 and T4 with 6.00 %. Highest incidence was recorded in T9 (18.00 %) which was on par with T1 (14.00 %).

Among the interaction effects no incidence was noticed in D2T4, D2T8, D3T2, D3T3, D3T4, D3T5, D3T6, D3T8, D3T10, D3T11 and D4T10. Maximum incidence of rhizoctonia blight was recorded for D1T9 (40.00 %) which was on par with D1T1 (32.00 %) and D1T10 (32.00 %).

Table 14. Effect of sowing dates, varieties and their interaction on incidence of leaf caterpillar and alternaria leaf spot of cabbage

Varieties	Leaf caterpillar (%)					Alternaria leaf spot (%)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	22.00	20.00	16.00	26.00	21.00	21.00	8.00	2.00	6.00	9.25
T2	8.00	9.00	6.00	11.00	8.50	10.00	2.00	2.00	2.00	4.00
T3	12.00	8.00	4.00	16.00	10.00	14.00	4.00	4.00	4.00	6.50
T4	10.00	8.00	7.00	16.00	10.25	10.00	6.00	2.00	4.00	5.50
T5	14.00	7.00	2.00	16.00	9.75	10.00	4.00	4.00	4.00	5.50
T6	10.00	8.00	4.00	24.00	11.50	18.00	4.00	4.00	8.00	8.50
T7	12.00	12.00	6.00	12.00	10.50	12.00	4.00	2.00	4.00	5.50
T8	11.00	8.00	6.00	8.00	8.25	10.00	2.00	2.00	2.00	4.00
T9	24.40	24.00	20.00	16.00	21.10	22.00	4.00	4.00	8.00	9.50
T10	12.00	6.00	14.00	20.00	13.00	20.00	6.00	4.00	6.00	9.00
T11	20.00	4.00	4.00	20.00	12.00	12.00	4.00	2.00	4.00	5.50
Mean	14.12	10.36	8.09	16.81		14.45	4.36	2.90	4.72	
CD (5%)	D				7.08					2.47
	T				8.19					3.14
	DxT				16.39					5.28

4.1.7.4 Head rot (*Aternaria brassicae*)

Incidence of head rot was significantly influenced by different sowing dates, varieties and their interactions (Table 15). Low incidence of head rot (0.73 %) was noticed in November 1st sowing which was on par with October 15th sowing (2.55 %) and November 15th sowing (3.27 %). Highest incidence (4.18 %) was recorded for October 1st sowing.

Lowest incidence was recorded for T2 (0.50 %) which was on par with T8 (0.50 %), T4 (1.00 %), T5 (1.50 %), T7 (1.50 %), T11 (2.00 %) and T6 (2.50 %). Highest incidence was observed in T1 (7.50 %) which was on par with T9 (5.00 %) and T10 (4.50 %).

Among the interaction effect no incidence was noticed in D2T2, D2T3, D2T4, D2T5, D2T7, D2T8, D3T2, D3T3, D3T4, D3T5, D3T6, D3T7, D3T8, D3T10, D3T11, D4T2, D4T3 and D4T8. Maximum incidence of head rot (12.00 %) was recorded for D1T1 and D1T3.

4.1.8 Weather parameters

The weather parameters during the crop period are presented in Appendix II and Fig 10. The maximum temperature ranged from 29.40 ^{0}C to 32.50 ^{0}C and the minimum temperature ranged from 20.80 ^{0}C to 24.30 ^{0}C during the crop period. The rainfall ranged from 0.00 to 34.00 mm and the relative humidity ranged from 89.60 to 99.00 %.

4.2 Genetic variability, heritability and genetic advance

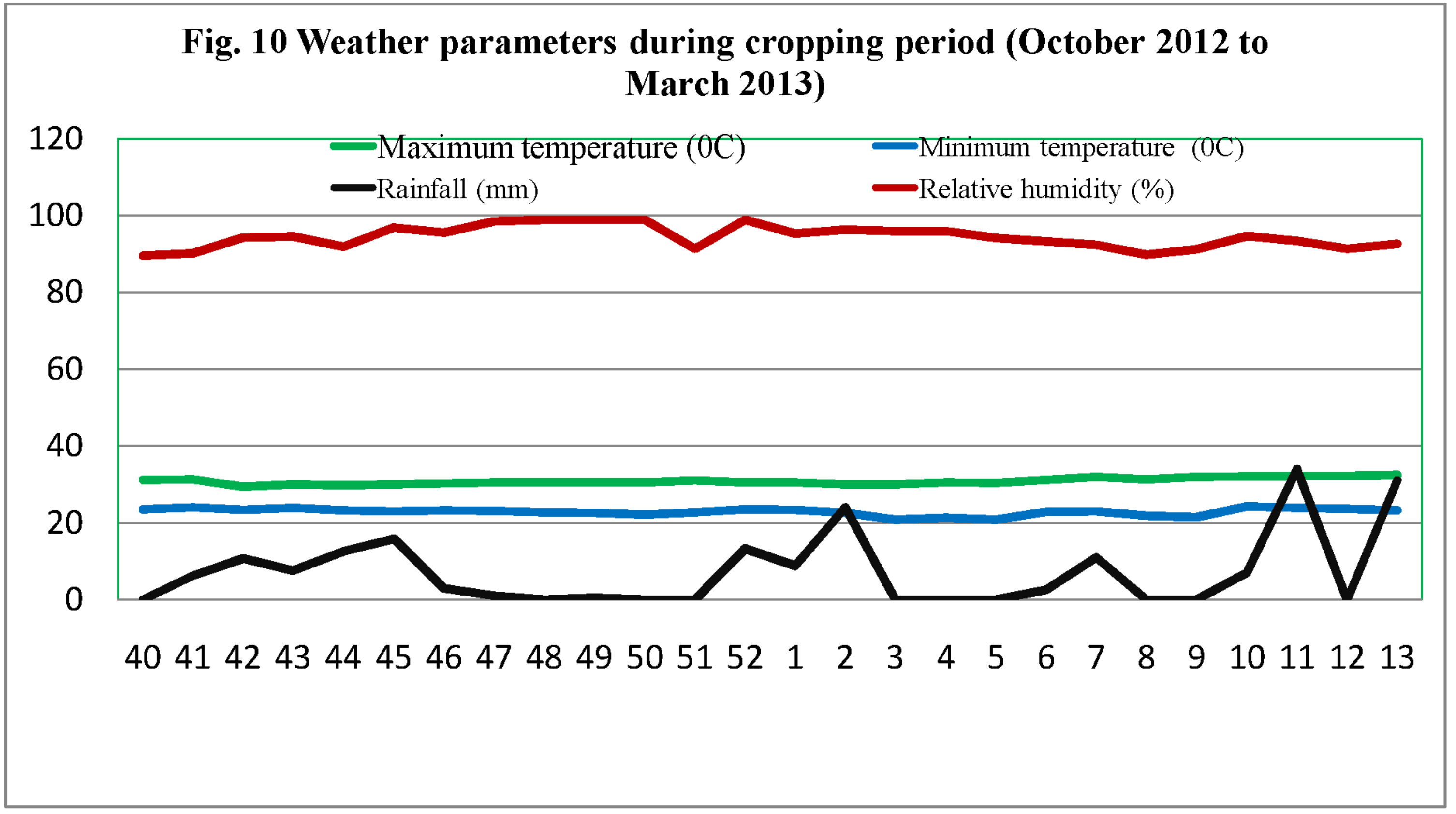
The population means, range, genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), heritability and genetic advance for 26 characters of cabbage were studied and are presented in Table 16 and Fig. 11 & 12.

4.2.1 Vegetative characters

Plant height ranged from 16.80 to 30.18 cm with a mean of 24.08 cm. The GCV was 16.64 and PCV was 18.95. Heritability was high (77.13 per cent) while genetic advance was 30.11.

Table 15. Effect of sowing dates, varieties and their interaction on incidence of rhizoctonia blight and head rot of cabbage

Varieties	Rhizoctonia blight (%)					Head rot (%)				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean
T1	32.00	12.00	4.00	8.00	14.00	12.00	6.00	4.00	8.00	7.50
T2	10.00	4.00	0.00	10.00	6.00	2.00	0.00	0.00	0.00	0.50
T3	24.00	4.00	0.00	10.00	9.50	12.00	0.00	0.00	0.00	3.00
T4	12.00	0.00	0.00	12.00	6.00	2.00	0.00	0.00	2.00	1.00
T5	28.00	8.00	0.00	4.00	10.00	4.00	0.00	0.00	2.00	1.50
T6	24.00	4.00	0.00	12.00	10.00	2.00	4.00	0.00	4.00	2.50
T7	13.20	8.00	4.00	4.00	7.30	2.00	0.00	0.00	4.00	1.50
T8	18.00	0.00	0.00	6.00	6.00	2.00	0.00	0.00	0.00	0.50
T9	40.00	16.00	8.00	8.00	18.00	4.00	8.00	4.00	4.00	5.00
T10	32.00	8.00	0.00	0.00	10.00	2.00	8.00	0.00	8.00	4.50
T11	12.00	8.00	0.00	8.00	7.00	2.00	2.00	0.00	4.00	2.00
Mean	22.29	6.54	1.45	7.45		4.18	2.55	0.73	3.27	
CD (5%)	D				1.87					2.41
	T				2.23					3.82
	DxT				4.46					7.65



Standard weeks

Non wrapper leaves per plant showed a range of 15.76 -19.00 and the mean was 17.04. GCV was 8.97 and PCV was 10.79. Heritability was high (69.21 per cent) while genetic advance was 15.49.

Gross plant weight ranged from 0.59-1.48 kg and showed a mean value of 0.96 kg. The GCV and PCV were 33.20 and 35.45 respectively. Heritability was high (87.72 per cent) and genetic advance was 63.54.

Leaf length ranged from 22.33-31.62 cm and showed a mean value of 26.23 cm. The GCV and PCV were 12.77 and 14.76 respectively. Heritability was high (74.88 per cent) and genetic advance was 22.76.

Leaf breadth ranged from 17.02 to 27.98 cm with a mean of 21.99 cm. The GCV was 13.29 and PCV was 14.71. Heritability was high (81.58 per cent) while genetic advance was 24.74.

Leaf size showed a range of 356.44 - 884.26 cm^2 and the mean was 585.94 cm^2. GCV was 24.94 and PCV was 27.57. Heritability was high (81.83 per cent) while genetic advance was 46.48.

4.2.2 Head characters

Days to head formation ranged from 36.43 - 57.17 days with a mean of 42.68 days. The GCV was 12.11and PCV was 12.55. Heritability was high (93.14 per cent) while genetic advance was 24.02.

Days to head harvest ranged from 62.33 - 95 days and showed a mean value of 72.38 days. The GCV and PCV were 10.71 and 11.64 respectively. Heritability was high (84.67per cent) and genetic advance was 21.12.

Days to head maturity showed a range of 66.53 - 95 days and the mean was 72.78 days. GCV was 9.77 and PCV was 10.42. Heritability was high (87.87per cent) while genetic advance was 20.17.

Head depth ranged from 7.5 - 12.78 cm and showed a mean value of 10.17 cm. The GCV and PCV were 13.79 cm and 14.87 cm respectively. Heritability was high (86.04 per cent) and genetic advance was 26.35.

Head diameter ranged from 5.88 to 12.49 cm with a mean of 10.00 cm. The GCV was 28.75 and PCV was 29.93. Heritability was high (92.27 per cent) while genetic advance was 56.90.

Head solidity showed a range of 37.4 - 57.69 g/cm^3 and the mean was 46.84 g/cm^3. GCV was 12.43 and PCV was 19.07. Heritability was moderate (42.49 per cent) while genetic advance was 16.69.

Core length ranged from 3.80 to 8.01 cm and showed a mean value of 5.39 cm. The GCV and PCV were 22.19 and 24.81 respectively. Heritability was high (80.02 per cent) and genetic advance was high (40.82).

4.2.3 Yield characters

Net head weight ranged from 152.00 - 876.67 g and showed a mean value of 500.91g. The GCV and PCV were 43.14 and 45.10 respectively. Heritability was high (91.47 per cent) and genetic advance was high (84.98).

Gross head weight ranged from 181.33 to 922.67 g with a mean of 533.46 g. The GCV was 42.26 and PCV was 44.19. Heritability was high (91.44 per cent) while genetic advance was high (83.26).

Harvest index showed a range of 0.17 - 0.64 and the mean was 0.49. GCV was 18.46 and PCV was 20.53. Heritability was high (80.85 per cent) while genetic advance was high (33.33).

Yield per plot ranged from 3.80 to 21.92 kg with a mean of 12.75 kg. The GCV was 43.14 and PCV was 45.10. Heritability was high (91.47 per cent) while genetic advance was 83.45.

4.2.4 Quality characters

Protein content ranged from 0.99 - 1.19 per cent and the mean was 1.06 per cent. GCV was 4.89 and PCV was 6.21. Heritability was high (62.16 per cent) while genetic advance was 38.68.

Vitamin A ranged from 652.21- 427.54 IU and showed a mean value of 503.11 IU. The GCV and PCV were 13.15 and 23.36 respectively. Heritability was moderate (31.72 per cent) and genetic advance was moderate (15.26).

Vitamin C ranged from 75.23 - 19.34 mg/100g and showed a mean value of 34.75 mg/100g. The GCV and PCV were 41.72 and 46.19 respectively. Heritability was high (81.58 per cent) and genetic advance was 77.64.

4.2.5 Incidence of physiological disorders

Percentage of burst head ranged from 0.00 to 8.00 with a mean of 1.82. The GCV was 21.25 and PCV was 27.66. Heritability was low (1.47per cent) while genetic advance was 44.50.

Incidence of multiple head showed a range of 0.00 to 10.00 per cent and the mean was 1.64 per cent. GCV was 24.99 and PCV was 34.86. Heritability was 38.36 per cent while genetic advance was 43.29.

4.2.6 Incidence of pest and diseases

Leaf caterpillar incidence ranged from 0.00 to 20.00 with an overall mean of 10.22 per cent. The GCV was 56.70 and PCV was 97.37. Heritability was moderate (33.92 per cent) while genetic advance was high (72.11).

Percentage of head rot showed a range of 0.00 to 12.00 and the mean was 2.18. GCV was 75.74 and PCV was 82.14. Heritability was (low) 27.63 per cent while genetic advance was high (89.82).

Table 16. Variability, heritability and genetic advance in cabbage

Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Net head weight (g)	152.00-876.67	500.91	43.14	45.10	91.47	425.69	84.98
Gross head weight (g)	181.33-922.67	533.46	42.26	44.19	91.44	444.14	83.26
Harvest index	0.17-0.64	0.49	18.46	20.53	80.85	0.17	33.33
Yield per plot (kg)	3.80-21.92	12.75	43.14	45.10	91.47	10.64	83.45
Protein (%)	0.99-1.19	1.06	4.89	6.21	62.16	0.41	38.68
Vitamin A (IU)	652.21-427.54	503.11	13.15	23.36	31.72	76.78	15.26
Vitamin C (mg/100g)	75.23-19.34	34.75	41.72	46.19	81.58	26.98	77.64
Burst head (%)	0.00-8.00	1.82	21.25	27.66	1.47	0.81	44.50
Multiple head (%)	0.00-10.00	1.64	24.99	34.86	38.36	0.71	43.29
Leaf caterpillar (%)	0.00-20.00	10.22	56.70	97.37	33.92	7.37	72.11
Alternaria leaf spot (%)	0.00-4.00	1.09	46.90	73.48	73.19	0.59	54.13
Rhizoctonia blight (%)	0.00-8.00	2.18	50.88	52.78	11.09	1.14	52.25
Head rot (%)	0.00-12.00	2.18	75.74	82.14	27.63	1.96	89.82

Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Plant height (cm)	16.80-30.18	24.08	16.64	18.95	77.13	7.25	30.11
Non wrapper leaves per plant	15.76-19.00	17.04	8.97	10.79	69.21	2.64	15.49
Gross plant weight (kg)	0.59-1.48	0.96	33.20	35.45	87.72	0.61	63.54
Leaf length (cm)	22.33-31.62	26.23	12.77	14.76	74.88	5.97	22.76
Leaf breadth (cm)	17.02-27.98	21.99	13.29	14.71	81.58	5.44	24.74
Leaf size (cm^2)	356.44-884.26	585.94	24.94	27.57	81.83	272.32	46.48
Day to head formation	36.43-57.17	42.68	12.11	12.55	93.14	10.25	24.02
Days to head harvest	64.33-95.00	72.56	10.71	11.64	84.67	15.29	21.12
Days to head maturity	66.53-95.00	73.78	9.77	10.42	87.87	14.68	20.17
Head depth (cm)	7.5-12.78	10.17	13.79	14.87	86.04	2.68	26.35
Head diameter (cm)	5.88-12.49	10.00	28.75	29.93	92.27	5.69	56.90
Head solidity (gm/cm^3)	37.4-57.69	46.84	12.43	19.07	42.49	7.82	16.69
Core length (cm)	3.8-8.01	5.39	22.19	24.81	80.02	2.20	40.82

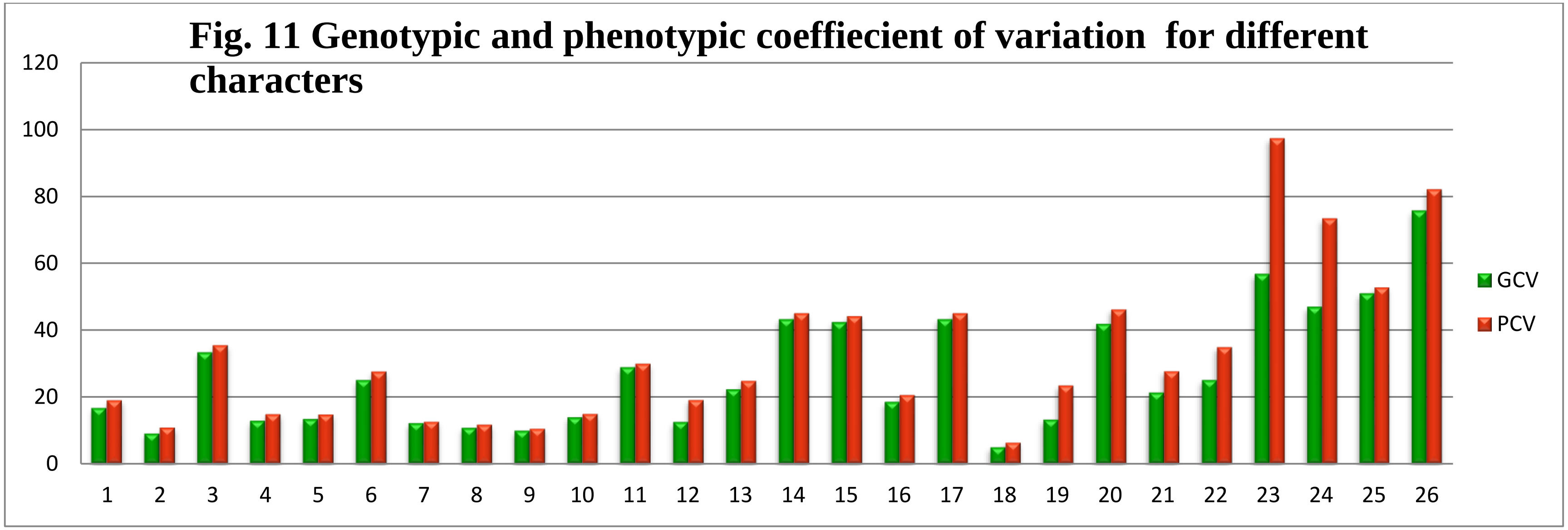
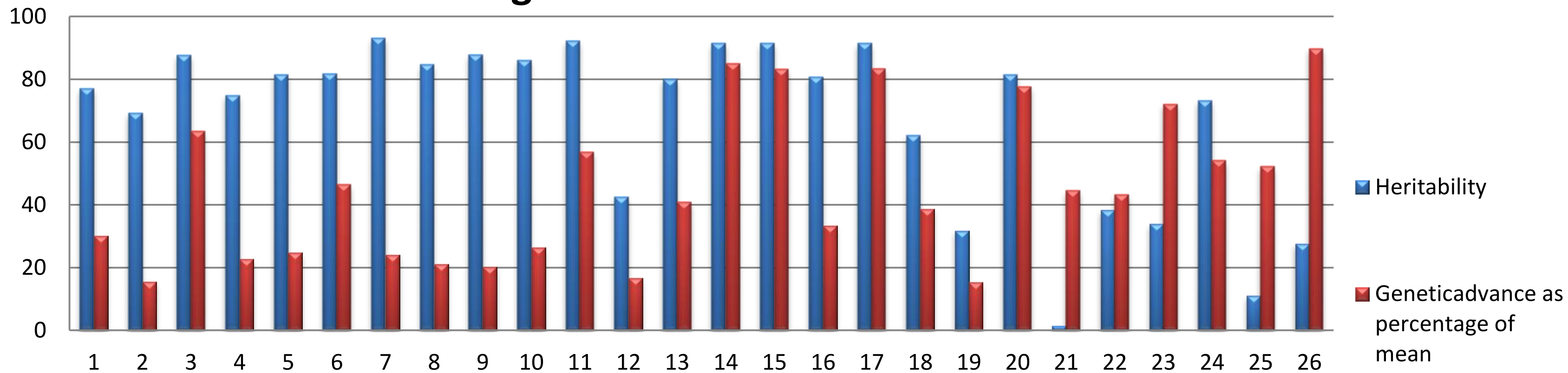


Fig. 11 Genotypic and phenotypic coeffiecient of variation for different characters

Characters

1) Plant height	6) Leaf size	11) Head diameter	16) Harvest index	21) % of burst head	26) % of alternaria leaf spot
2) Non wrapper leaves/plant	7) Days to head formation	12) Head solidity	17) Yield per plot	22) % of multiple head	
3) Gross plant weight	8) Days to head harvest	13) Core length	18) Protein	23) % of Leaf caterpillar	
4) Leaf length	9) Days to head maturity	14) Net head weight	19) Vitamin A	24) % of head rot	
5) Leaf breadth	10) Head depth	15) Gross head weight	20) Vitamin C	25) % of Rhizoctonia blight	

Fig. 12 Heritabilty and genetic advance as percentage of mean in cabbage varieties for different characters



Characters

1) Plant height 6) Leaf size 11) Head diameter 16) Harvest index 21) % of burst head 26) % of alternaria leaf spot

2) Non wrapper leaves/plant 7) Days to head formation 12) Head solidity 17) Yield per plot 22) % of multiple head

3) Gross plant weight 8) Days to head harvest 13) Core length 18) Protein 23) % of Leaf caterpillar

4) Leaf length 9) Days to head maturity 14) Net head weight 19) Vitamin A 24) % of head rot

5) Leaf breadth 10) Head depth 15) Gross head weight 20) Vitamin C 25) % of Rhizoctonia blight

Rhizoctonia blight ranged from 0.00 to 8.00 with a mean value of 2.18. The GCV and PCV were 50.88 and 52.78 respectively. Heritability was low (11.09 per cent) while genetic advance was high (52.25).

Percentage of alternaria leaf spot ranged from 0.00 to 4.00 and showed a mean value of 1.09. The GCV and PCV were 46.90 and 73.48 respectively. Heritability was 73.19 per cent while genetic advance was 54.13.

4.3 Correlation studies

The phenotypic, genotypic and environmental correlation among 18 vegetative, head and yield characters were worked out and are presented in tables 17, 19 and 21 respectively. Incidence of physiological disorders, pest and diseases with yield characters were computed and presented in Tables 18, 20 and 22 respectively.

4.3.1 Phenotypic Correlation Coefficients

4.3.1.1 Correlation between yield and other characters

Net head weight showed significant positive correlation with plant height (0.5246), non-wrapper leaves per plant (0.3369), gross plant weight (0.9302), leaf size (0.4821), head depth (0.4803), head diameter (0.9470), and core length (0.5571). It exhibited had negative correlation with days to head formation (-0.4975), days to head maturity (-0.5802), days to head harvest (-0.6041) and head solidity (-0.2235) Table (17).

4.3.1.2 Correlation among the yield component characters

Plant height had high positive correlation with non wrapper per plant (0.5517), gross plant weight (0.6558), leaf size (0.7092), head diameter (0.5658), core length (0.4934), net head weight (0.5246) and gross head weight (0.5389).

Non wrapper leaves per plant showed positive significant correlation with gross plant weight (0.4880), leaf size (0.5466), head diameter (0.4011), core length (0.5718), net head weight (0.3369), gross head weight (0.3536) and days to head formation (0.2456).

Gross plant weight exhibited positive correlation with leaf size (0.5992), head diameter (0.8941), core length (0.5766), net head weight (0.9302), gross head weight (0.9368) and vitamin A content (0.4843).Leaf size showed significant positive correlation with head diameter (0.4639), core length (0.4433), net head weight (0.4821), gross head weight (0.4965), vitamin A content (0.4641) and vitamin C (4224).

Days to head formation showed significant positive correlated with plant height (0.1934), non wrapper leaves per plant (0.2456), leaf size (2451), days to head maturity (0.6904), days to head harvest (0.7773) and protein (0.5208).

Days to head maturity was positively correlated with days to head formation (0.6904), days to head harvest (0.9202), head solidity (0.5053) and vitamin C (0.6122).

Days to head harvest showed positive correlation with days to head formation (0.7773), days to head maturity (0.9202), head solidity (0.4859) and protein (0.3824).

Head depth showed positive correlation with gross plant weight (0.3058), harvest index (0.6422), head diameter (0.3367), core length (0.4174), net head weight (0.4803), gross head weight (0.4733), harvest index (0.6422) and vitamin C (0.5647).

Head diameter had high positive correlation with plant weight (0.5658), non wrapper leaves per plant (0.4011), gross plant weight (0.8941), leaf size (0.4639) and head depth (0.3367).

Head solidity had high positive correlation with days to head maturity (0.5053) and days to head harvest (0.4859).

Core length showed positive correlation with plant height (0.4934), non wrapper leaves per plant (0.5718), gross plant weight (0.5766), leaf size (0.4433),head depth (0.4174), head diameter (0.5637), net head weight (0.5571) and gross head weight (0.5687).

Table 17. Phenotypic correlation coefficients for vegetative, head and yield characters

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17
X1	1.0000																
X2	0.5517**	1.0000															
X3	0.6558**	0.4880**	1.0000														
X4	0.7092**	0.5466**	0.5992**	1.0000													
X5	0.1934	0.2456	-0.2763*	0.2451	1.0000												
X6	0.0402	0.0603	-0.3571**	0.0925	0.6904**	1.0000											
X7	0.0771	-0.0213	-0.4002**	0.1227	0.7773**	0.9202**	1.0000										
X8	-0.1057	-0.1136	0.3058*	-0.0925	-0.4230**	-0.7977**	-0.7259**	1.0000									
X9	0.5658**	0.4011**	0.8941**	0.4639**	-0.5099**	-0.5153	-0.5770	0.3367**	1.0000								
X10	-0.0744	-0.1578	-0.0860	-0.0295	0.1503	0.5053**	0.4859**	-0.5791**	-0.3193*	1.0000							
X11	0.4934**	0.5718**	0.5766**	0.4433**	0.0081	-0.3848	-0.3938**	0.4174**	0.5637**	-0.5311**	1.0000						
X12	0.5246**	0.3369**	0.9302**	0.4821**	-0.4975**	-0.5802	-0.6041**	0.4803**	0.9470**	-0.2235	0.5571**	1.0000					
X13	0.5389**	0.3536**	0.9368**	0.4965**	-0.4791**	-0.5723	-0.5948**	0.4733**	0.9478**	-0.2266	0.5687**	0.9986**	1.0000				
X14	-0.1255	-0.2142	0.3047*	-0.1671	-0.7925**	-0.7920	-0.7834**	0.6422**	0.5531**	-0.3324**	0.1886	0.6063**	0.5885**	1.0000			
X15	-0.0356	0.2583*	-0.2735*	0.1208	0.5208**	0.4249**	0.3824**	-0.3043*	-0.3536**	0.0407	0.1999	-0.3833**	-0.3745**	-0.4968**	1.0000		
X16	0.4417**	0.2547*	0.4843**	0.4641**	-0.0080	-0.1858	-0.1160	0.0565	0.3825**	0.0751	0.1850	0.4469**	0.4534**	0.0768	-0.2419	1.0000	
X17	0.5083**	0.5064**	0.0101	0.4224**	0.7414**	0.6122**	0.6122**	0.5647**	-0.1430	0.1331	0.2002	-0.2050	-0.1850	-0.6418**	0.4267**	-0.0197	1.0000

X1. Plant height (cm)
X2. Non wrapper leaves per plant
X3. Gross plant weight (kg)
X4. Leaf size (cm^2)
X5.Days to head formation
X6. Days to head maturity
X7. Days to head harvest
X8. Head depth (cm)
X9. Head diameter (cm)
X10. Head solidity (g/cm^3)
X11. Core length (cm)
X12. Net head weight (g)
X13. Gross head weight (g)
X14. Harvest index
X15. Protein (%)
X16. Carotene (IU)
X17. Vitamin C (mg/100g

Table 18. Phenotypic correlation coefficients for yield, incidence of physiological disorders, pests and diseases

Character	X1	X2	X3	X4	X5	X6	X7
X1	1.0000						
X2	-0.9986**	1.0000					
X3	-0.6063**	0.1101	1.0000				
X4	-0.3786**	0.1058	0.3784**	1.0000			
X5	-0.3833**	0.0987	0.3501**	0.0375	1.0000		
X6	-0.4469**	0.2090	0.2717*	0.3865**	0.2719*	1.0000	
X7	-0.2050	-0.0644	0.2596*	0.0552	0.0630	-0.0553	1.0000

X1. Net head weight (g) X2. % of burst head

X3. % of multiple head X4. Incidence of leaf caterpillar (%)

X5. Incidence of head rot (%) X6. Incidence of rhizoctonia blight (%)

X7. Incidence of alternaria leaf spot (%)

Gross head weight had high positive correlation with plant weight (0.5389), non wrapper leaves per plant (0.3536), gross plant weight (0.9368), leaf size (0.4965), head depth (0.4733), head diameter (0.9478), core length (0.5687), net head weight (0.9986) and harvest index (0.5885).

Harvest index was positively correlated with gross plant weight (0.3047), head depth (0.6422), head diameter (0.5531) and gross head weight (0.5885).

Protein was positively correlated with days to head formation (0.5208), days to maturity (0.4249) and days to head harvest (0.3824). Vitamin A had positive correlation with plant height (0.4417), gross plant weight (0.9302), leaf size (0.4641), head diameter (0.9470), net head weight (0.4469) and gross head weight (0.4534). Vitamin C had positive correlation with plant height (0.5083), non-wrapper leaves per plant (0.5064) and days to head formation (0.7414).

Incidence of physiological disorders like burst head (0.9986), multiple head (-0.6063) pest like leaf caterpillar (-0.3786) and diseases like head rot (-0.3833), rhizoctonia blight (-0.4469) and alernaria leaf spot (-0.2050) showed negative correlation with net head weight.

4.3.2 Genotypic correlation

Genotypic correlation coefficients were in general higher than phenotypic correlation for the characters under study.

4.3.2.1Correlation between yield and other characters

High positive significant correlation was observed between net head weight and plant height (0.6416), non wrapper leaves per plant (0.4296), gross plant weight (0.9566) and head diameter (0.9796). Net head weight also exhibited positive correlation with core length (0.5901) and leaf size (0.5405). High negative correlation was found between net head weight and days to head formation (-0.5521), days to head maturity (-0.6394), days to head harvest (-0.6722), head depth (-0.4660) and head solidity (-0.3859) (Table 19).

4.3.2.2 Correlation among the yield component characters

Plant height had positive correlation with non wrapper leaves per plant (0.8230), leaf size (0.9451), head diameter (0.6646), core length (0.6157), net head weight (0.6416), gross head weight (0.6601) and vitamin A (0.8775).

Non wrapper leaves per plant showed positive correlation with gross plant weight (0.6105), leaf size (0.7250), head diameter (0.4993) core length (0.8261), net head weight (0.4296), gross plant weight (0.4554), protein (0.4461), vitamin A (0.4029) and vitamin C (0.7036).

Gross plant weight showed positive correlation with plant height (0.8230), non wrapper leaves per plant (0.6105), leaf size (0.7254), head diameter (0.9396), core length (0.6097), net head weight (0.9566) and gross head weight (0.9561).

Leaf size had positive correlation with plant height (0.9451), non wrapper leaves per plant (0.7250), gross plant weight (0.7254), core length (0.5446), net head weight (0.5405), gross head weight (0.5567) and vitamin A (0.8496).

Days to head formation showed positive correlation with plant height (0.2466), non wrapper leaves per plant (0.2974), leaf size (0.3163), days to head maturity (0.7172), days to head harvest (0.8203) and protein (0.6677).

Days to head maturity showed positive correlation with days to head formation (0.7172), days to head harvest (0.9785) and head solidity (0.8211).

Days to head harvest exhibited a positive correlation with days to head formation (0.8203), days to maturity (0.9785), head solidity (0.7199) and protein (0.5796).

Head depth exhibited a positive correlation with core length (0.4087), gross plant weight (0.4573) and harvest index (0.7014).

Head diameter also exhibited positive correlation with plant height (0.6646), non wrapper leaves per plant (0.4993), gross plant weight (0.9369), leaf size

(0.5411), core length (0.5909), net head weight (0.9796), gross head weight (0.9782) and harvest index (0.0.6240).

Head solidity showed positive correlation with days to head maturity (0.8211), days to head harvest (0.7199), core length (0.5909), net head weight (0.9796), gross head weight (0.9782), harvest index (0.6240) and vitamin A (0.7919).

Core length exhibited a positive correlation with plant height (0.6157), non wrapper leaves per plant (0.8261), gross plant weight (0.6097), leaf size (0.5446), head depth (0.4087), head diameter (0.5909), net head weight (0.5901), gross head weight (0.6040), and vitamin A (0.4650).

Gross head showed positive correlation with plant height (0.6601), non wrapper leaves per plant (0.4554), gross plant weight (0.9561), leaf size (0.5567), head depth (0.4573), head diameter (0.9752), core length (0.6040), net head weight (0.9996) and harvest index (0.6162).

Harvest index had positive correlation with gross head plant weight (0.3831), head depth (0.7014), head diameter (0.6240), net head weight (0.6380) and gross head weight (0.6162).

Protein percentage exhibited significant positive correlation with non wrapper leaves per plant (0.4461), days to head formation (0.6677), days to head maturity (0.6286) and days to head harvest (0.5796).

Vitamin A exhibited positive correlation with exhibited significant positive correlation plant height (0.8775), non wrapper leaves per plant (0.4929), gross plant height (0.9950), leaf size (0.8496), head depth (0.3866), head diameter (0.7919), core length (0.4650), net head weight (0.9087) and gross head weight (0.9236).

Vitamin C exhibited positive correlation with of plant height (0.5145), non wrapper leaves per plant (0.7036), leaf size (0.5638), days to head formation (0.8471), days to maturity (0.7068) and days to head harvest (0.7054).

Table 19. Genotypic correlation coefficients for vegetative, head and yield characters

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17
X1	1.0000																
X2	0.8186**	1.0000															
X3	0.8230**	0.6105**	1.0000														
X4	0.9451**	0.7250**	0.7254**	1.0000													
X5	0.2466	0.2974*	-0.3359**	0.3163*	1.0000												
X6	0.0884	0.0957	-0.4086**	0.2389	0.7172**	1.0000											
X7	0.0848	0.0161	-0.4522**	0.1525	0.8203**	0.9785**	1.0000										
X8	-0.1285	-0.1920	0.2848*	-0.1224	-0.4675**	-0.9027**	-0.8142**	1.0000									
X9	0.6646**	0.4993**	0.9396**	0.5411**	-0.5661**	-0.5612**	-0.6284**	0.3078*	1.0000								
X10	-0.0281	-0.1588	-0.1889	-0.0570	0.2137	0.8211**	0.7199**	-0.7260**	-0.3147	1.0000							
X11	0.6157**	0.8261**	0.6097**	0.5446**	-0.0253	-0.4440**	-0.4747**	0.4087**	0.5909**	-0.7502**	1.0000						
X12	0.6416**	0.4296**	0.9566**	0.5405**	-0.5521**	-0.6304**	-0.6722**	-0.4660**	0.9796**	-0.3859**	0.5901**	1.0000					
X13	0.6601**	0.4554**	0.9561**	0.5567**	-0.5299**	-0.6180**	-0.6604**	0.4573**	0.9782**	-0.3791**	0.6040**	0.9996**	1.0000				
X14	-0.1503	-0.2499	0.3831**	-0.2539	-0.9047**	-0.9095**	-0.9467**	0.7014**	0.6240**	-0.6505**	0.2298	0.6380**	0.6162**	1.0000			
X15	0.0224	0.4461**	-0.4053**	0.1921	0.6677**	0.6286**	0.5796**	-0.4543**	-0.5047**	0.0531**	0.2298	-0.5647**	-0.5516**	-0.7488**	1.0000		
X16	0.8775**	0.4029**	0.9950**	0.8496**	-0.0350	-0.2668*	-0.2447	0.3866**	0.7919**	-0.2028	0.4650**	0.9087**	0.9232**	0.2469	-0.5348	1.0000	
X17	0.5145**	0.7036**	-0.0061	0.5638**	0.8471**	0.7068**	0.7054**	-0.6875**	-0.1559	0.1868	0.2092	-0.2462**	-0.2202	-0.7998**	0.6770**	0.1491	1.0000

X1. Plant height (cm)
X2. Non wrapper leaves per plant
X3. Gross plant weight (kg)
X4. Leaf size (cm^2)
X5.Days to head formation
X6. Days to head maturity
X7. Days to head harvest
X8. Head depth
X9. Head diameter
X10. Head solidity (g/cm^3)
X11. Core length (cm)
X12. Net head weight (g)
X13. Gross head weight (g)
X14. Harvest index
X15. Protein (%)
X16. Vitamin A (IU)
X17. Vitamin C (mg/100g)

Table 20. Genotypic correlation coefficients for yield, incidence of physiological disorders, pests and diseases

Character	X1	X2	X3	X4	X5	X6	X7
X1	1.0000						
X2	-0.9996**	1.0000					
X3	-0.6380**	-0.5015**	1.0000				
X4	-0.3867**	0.6594**	0.8642**	1.0000			
X5	-0.5647**	0.3132*	0.6663**	0.4047**	1.0000		
X6	-0.9087**	0.2875*	0.9196**	0.3014*	0.4854**	1.0000	
X7	-0.2462	0.2228	0.3430**	0.1041	0.0614	0.2086	1.0000

X1. Net head weight (g) X2. % of burst head

X3. % of multiple head X4. Incidence of leaf caterpillar (%)

X5. Incidence of head rot (%) X6. Incidence of rhizoctonia blight (%)

X7. Incidence of alternaria leaf spot (%)

Table 21. Error correlation coefficients for vegetative, head and yield characters

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X16	X17	X18
X1	1.0000																
X2	-0.1743	1.0000															
X3	-0.1252	0.0636	1.0000														
X4	-0.2032	0.0046	-0.1028	1.0000													
X5	-0.1236	0.0495	0.2962*	-0.2766*	1.0000												
X6	-0.1951	-0.0745	0.0138	-0.1182	0.4566**	1.0000											
X7	0.0460	-0.1549	-0.0761	-0.0256	0.4764**	0.5588**	1.0000										
X8	-0.0059	0.1667	0.4463**	0.0636	-0.0474	-0.0985	-0.2119	1.0000									
X9	0.0395	0.0133	0.5249**	-0.0524	0.2015	-0.1030	-0.1980	0.6016**	1.0000								
X10	-0.1607	-0.1705	0.1097	0.0126	0.0797	0.0135	0.1821	-0.4946**	-0.5799**	1.0000							
X11	0.0459	-0.1735	0.4199**	0.0121	0.2549*	-0.0803	-0.0175	0.4686**	0.4500**	-0.2764*	1.0000						
X12	-0.1016	-0.0301	0.7164**	0.1161	0.1568	-0.1479	-0.1097	0.6124**	0.5788**	0.0770	0.3986**	1.0000					
X13	-0.1094	-0.0537	0.7065**	0.1199	0.1275	-0.1805	-0.1195	0.6192**	0.6051**	0.0437	0.3980**	0.9882**	1.0000				
X14	-0.0325	-0.1124	-0.1173	0.2111	-0.0663	-0.1666	-0.0004	0.3497**	0.1158	0.1474	0.0192	0.4514**	0.4576**	1.0000			
X15	-0.1737	-0.1006	0.1195	-0.0616	0.0798	-0.1854	-0.1582	0.1217	0.1673	0.0287	0.1452	0.2367	0.2304	0.1264	1.0000		
X16	0.0195	0.1438	-0.1399	0.0888	0.0474	-0.1560	0.0336	-0.4713	-0.1998	0.2386	-0.1335	-0.1762	-0.1814	-0.1335	-0.0086	1.0000	
X17	0.4883**	-0.0937	0.1011	-0.2090	0.0274	0.0920	0.2434	0.0704	-0.0654	0.0710	0.1627	0.0611	0.0415	0.0412	-0.2099	-0.2694	1.0000

X1. Plant height (cm)
X2. Non wrapper leaves per plant
X3. Gross plant weight (kg)
X4. Leaf size (cm^2)
X5.Days to head formation
X6. Days to head maturity
X7. Days to head harvest
X8. Head depth
X9. Head diameter
X10. Head solidity (g/cm^3)
X11. Core length (cm)
X12. Net head weight (g)
X13. Gross head weight (g)
X14. Harvest index
X15. Protein (%)
X16. Vitamin A (IU)
X17. Vitamin C (mg/100g)

Table 22. Error correlation coefficients for yield, incidence of physiological disorders, pests and diseases

Character	X1	X2	X3	X4	X5	X6	X7
X1	1.0000						
X2	-0.9882	1.0000					
X3	-0.4514	0.1896	1.0000				
X4	-0.3687	-0.0142	0.1046	1.0000			
X5	-0.2367	0.0178	0.1994	-0.1249	1.0000		
X6	-0.1762	0.0383	0.1108	0.1749	0.2330	1.0000	
X7	0.0611	-0.1436	0.0459	-0.1516	-0.1073	-0.2800	1.0000

X1. Net head weight (g) X2. % of burst head

X3. % of multiple head X4. Incidence of spodoptera incidence (%)

X5. Incidence of head rot (%) X6. Incidence of rhizoctonia blight (%)

X7. Incidence of alternaria leaf spot (%)

4.3.3 Error correlation coefficient

Most of the error correlation coefficients were very low (Table21).

4.4 Path Coefficient Analysis

In path analysis, the genotypic correlation coefficients among yield and its component character were partitioned into direct and indirect contribution of each character to net head weight (Table 23). Non-wrapper leaves per plant, leaf size, days to head formation, days to head harvest, head solidity and core length were selected for path coefficient analysis.

Leaf size exhibited the highest positive direct effect on net head weight (0.7828) followed by non wrapper leaves per plant (0.2560) and core length (0.2953). Days to head harvest (-1.6347), days to head formation (-1.3409) and head solidity (-1.1768) exhibited negative direct effect on net head weight.

Non wrapper leaves per plant had genotypic correlation of 0.4296 with net head weight. In this, direct effect of non wrapper leaves per plant was 0.2560. Major portion of indirect effect was through leaf size (0.5675).Leaf size exhibited highest positive direct effect on net head weight (0.7828) whiles the genotype correlation with yield was 0.5405. Leaf size had major indirect effect on net head weight through non wrapper leaves per plant (0.1862).The direct effect of core length on net head weight was 0.2953 while genotypic correlation with yield was 0.5901. The core length had indirect effect on net head weight mainly through non wrapper leaves per plant (0.4946) and leaf size (0.3543). Days to head formation (-0.0091), days to head harvest (-0.2421) and head solidity (-0.3029) exhibited negative direct effect on net head weight.

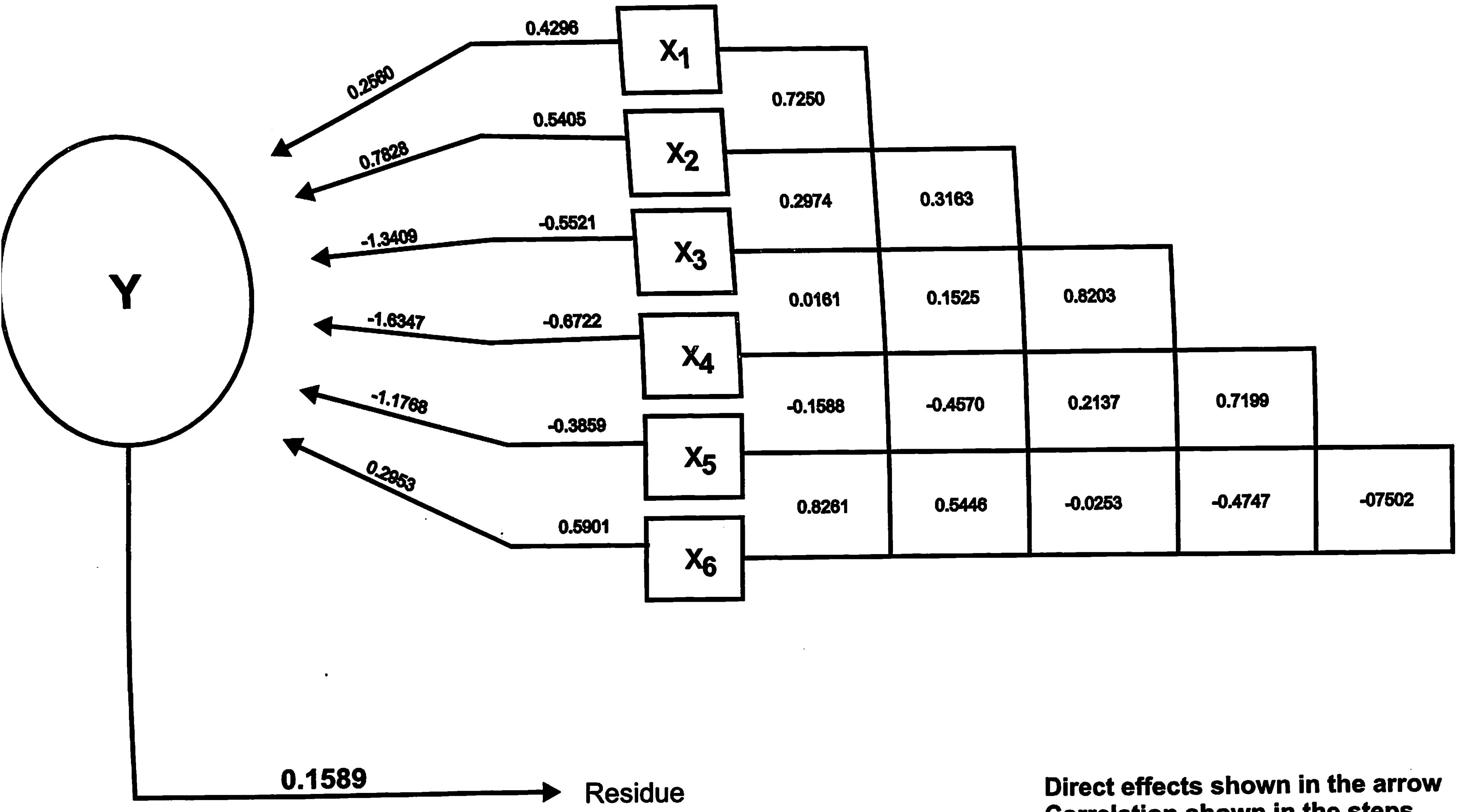
Days to head formation had a genotypic correlation of-0.5521 with net head weight. In this, the direct effect was -1.3409. The character exhibited indirect effect on net head weight through non wrapper leaves per plant (0.0764), leaf size (0.2476), days to head harvest (0.3606), head solidity (0.0917) and core length (0.0125).

Table 23. Direct and indirect effect of yield component of cabbage

Characters	Non wrapper leaves per plant	Leaf size	Days to head formation	Days to head harvest	Head solidity	Core length	Total correlation
Non wrapper leaves per plant	<u>0.2560</u>	0.5675	0.1073	-0.0263	-0.0681	-0.4076	0.4296
Leaf size	0.1862	<u>0.7828</u>	0.1141	-0.2493	-0.0245	-0.2689	0.5405
Days to head formation	0.0764	0.2476	<u>-1.3409</u>	0.3606	0.0917	0.0125	-0.5521
Days to head harvest	0.0041	0.1194	0.2958	<u>-1.6347</u>	0.3089	0.2342	-0.6722
Head solidity	-0.0408	-0.0446	0.0771	0.4291	<u>-1.1768</u>	0.3702	-0.3859
Core length	0.4946	0.3543	-0.0091	-0.2421	-0.3029	<u>0.2953</u>	0.5901

Residue= 0.1539 (Underlined figures are direct effect)

Fig. 13 path diagram showing direct and indirect effect of yield components on total yield of cabbage



Direct effects shown in the arrow
Correlation shown in the steps

Days to head harvest had a genotypic correlation of -0.6722 with net head weight. In this, the direct effect was -1.6347. Indirect effect through non wrapper leaves per plant (0.0041), leaf size (0.1194), days to head formation (0.2958), head solidity (0.3089), and core length (0.2342) also contributed to net head weight.

Head solidity had a genotypic correlation of -0.3859 with net head weight. In this, the direct effect was -1.1768. Indirect effect through non wrapper leaves per plant (-0.0408), leaf size (-0.0446), days to head formation (0.0771),days to head harvest (0.4291), and core length (0.3702) also contributed to net head weight.The residue 0.1539 indicating that selected six characters contributing the remaining eighty five per cent.

4.5 Selection Index

A discriminate function analysis was carried out for isolating superior genotypes.

Selection index involving characters *viz.,* plant height (X_1),non wrapper leaves per plant (X_2), leaf size (X_4), days to head formation (X_5), days to head maturity (X_6), days to head harvest (X_7), head depth (X_8), head diameter (X_9), head solidity (X_{10}), net head weight (X_{12}), gross head weight (X_{13}), harvest index (X_{14}), protein (X_{16}), carotene (X_{17}) and vitamin C (X_{18}).

$$I = 26.8991\ X_1 + 3.4708\ X_2 + 0.8673\ X_4 + 0.1631\ X_5 + 4.4756\ X_6 + -8.3788\ X_7 + 10.4086\ X_8 + 22.4505\ X_9 + -2.7533\ X_{10} + -10.7344\ X_{12} + 0.4106\ X_{13} + -3.8567\ X_{14} + -423.7794\ X_{16} + 0.3788\ X_{17} + -0.1252\ X_{18}$$

The index value for each variety was determined and they were ranked. The scores obtained for the varieties based on the selection index were given in Table 24. Based on the selection index including both vegetative and qualitative characters T2 (New Orient) was ranked first with an index of 11747.35 followed by NS 183 (T8) (9539.32). BC 38 (T9) and Asia Cross (T10) obtained next two positions with indices of 9064.221, 8152.672. The minimum scores were obtained for Gayatri (T3) with an index of 3444.955.

Table 24. Cabbage varieties ranked according to selection index

Rank	Varieties	Index
1	New Orient	11747.35
2	NS 183	9539.322
3	BC-38	9064.221
4	Asia Cross	8152.672
5	Summer Cross	6779.143
6	Indam Radha	6011.986
7	Veer- 333	5165.151
8	Indam 296	5133.426
9	Red C-05	4824.258
10	Indam Radha	4081.137
11	Gayatri	3444.955

Table 25. Genetic cataloguing of cabbage varieties used for the study

Characters	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Seedling leaf colour	1	1	5	1	1	4	1	1	1	1	6
Seedling leaf margin serration	2	2	1	2	2	1	2	2	2	2	2
Plant: attitude of outer leaves	5	5	3	3	3	3	3	3	5	5	3
Outer leaf: shape of blade	4	4	2	5	2	5	5	5	4	4	5
Leaf colour	2	2	2	1	1	1	2	1	2	2	4
Leaf waxiness	5	3	1	5	7	7	5	7	5	5	9
Undulation of leaf margin	5	7	3	3	1	5	3	3	5	5	5
Head shape	3	3	2	2	1	4	2	1	3	3	2
Shape of head in longitudinal section	1	2	4	4	4	5	4	5	2	2	4
Shape of head base in longitudinal section	1	1	1	1	1	1	1	1	1	1	1
Head length	5	5	3	3	3	5	3	7	5	5	5
Head diameter	5	7	3	3	3	5	3	5	7	5	3
Head : position of maximum diameter	2	2	2	1	2	1	2	2	2	2	2
Head cover	3	3	3	3	3	2	3	3	3	3	3
Head anthocyanin colouration	1	1	1	1	3	3	1	3	1	1	7
Head : internal colour	1	2	1	1	1	2	1	1	2	2	4
Head density	5	7	7	7	7	7	7	7	5	5	7
Head internal structure	7	5	5	5	5	5	5	5	7	7	5

DISCUSSION

5. DISCUSSION

Investigations were conducted at the Department of Olericulture, College of Agriculture, Vellayani to identify tropical cabbage varieties suitable for plains of southern Kerala and the best date of planting for yield and quality during the period from October 2012 to March 2013. The experiment was laid out in split plot design with four dates of sowing in main plot and eleven varieties in sub plots. In this chapter, attempt is being made to discuss salient experimental findings and to offer possible explanations and evidences with a view to determine the cause and effect relationships with regard to different characters.

The experimental results are discussed under different headings.

5.1 Effect of sowing dates

The study included four sowing dates *viz.* October 1st, October 15th, November 1st and November 15th and eleven varieties of cabbage. The response of cabbage to different sowing dates, varieties and their interaction revealed significant difference with respect to vegetative, head and yield characters and incidence of physiological disorders, pest and diseases.

5.1.1 Vegetative characters

In the present study, November 1st sowing resulted in maximum plant height, non wrapper leaves per plant, gross plant weight, leaf length, leaf breadth and leaf size. These results are in agreement with the findings of Shaker (1999), Sharma and Sharma (2001), Singh *et al.* (2010) and Singhal *et al.* (2009). The better plant growth of November 1st sowing may be due to conducive climatic condition which in turn resulted in high dry matter accumulation.

Among the varieties New Orient and NS 183 excelled other varieties in overall performance with respect to all the vegetative characters like plant height, leaves per plant, gross plant weight, leaf length, leaf breadth and leaf size whereas, Gayatri recorded the least values. The variety NS 183 was earlier reported as the suitable variety for the warm humid tropics of Kerala (Narayanankutty *et al.*, 2012). Varietal variation for vegetative characters of cabbage was reported by Rai and Singh (2000), Sharma (2001), Ijoyah and Rakotoavo (2007), Singh *et al.*(2011), Meena *et al*. (2012), Hasan and Solaiman (2012) and Kumar *et al*. (2013).

Interaction effects for dates of sowing and varieties were also significant for all vegetative characters. Cumulative effect of best sowing date and variety for vegetative characters were reflected in their interaction too. Maximum plant height and non wrapper leaves per plant were recorded for November 1st sowing of Red C-05 and BC- 38 whereas, highest gross plant weight and leaf size were recorded for November 1st sowing of NS 183 and New Orient. Findings of Kumar *et al*. (2000), Sharma (2001), Chaubey (2006) and Khan and Yadav (2010) were in line with the present results.

5.1.2 Earliness

Earliness in head initiation, maturity and harvest are preferred characters in cabbage since the duration of winter is too short in Kerala especially in the plains. According to Cooper (2000) days to head initiation was influenced by temperature and reported that an optimal temperature range of 20 to 30^{0}C is ideal for cabbage which supports the present findings. Differences in day light hours and temperature also affect the number of days to maturity in cabbage (Greenland *et al*., 2000).

In the present study, the days to head formation, harvest and maturity were significantly altered by sowing dates, varieties and their interaction. November 1st sowing resulted in early head formation (43.26 days) harvest (72.56 days) and maturity (73.78 days). The better weather condition prevailed during head initiation stage (minimum 20.8 ^{0}C and maximum 30.6 ^{0}C) might have resulted in early head formation, harvest and maturity. These finding are in conformity with the finding of Sharma and Sharma (2001).

Among the varieties, NS 183 and New Orient were the earliest and the late one was Red C- 05 which is a mid season variety. A cabbage forms its head during the vegetative growth period. The number and size of head leaves increase until the head acquires a weight, size and tightness suitable for harvest. So the earliness of head formation in cabbage varieties can be considered as the number of days after transplanting required for the head to attain a maximum weight. Early head forming cultivars exhibit larger primary wrapper leaves, earlier leaf widening with the increase of the leaf position and a lower LPH value (leaf position at which head formation started) than later head forming cultivars (Tanka and Nikura 2003). Tanaka *et al.* (2008) suggested that leaf position at which head formation started (LPH) was a useful criterion for the development of early head forming spring cultivars. Similar variation among genotypes for earliness was reported by many workers (Kumar, 1998; Ijoyah and Rakotomavo, 2007 and Kumar, 2013).

November 1st sowing of NS 183 and New Orient resulted in earliest head formation (40.23 & 40.53 days), head harvest (64.20 & 64.40 days) respectively. Interactions between sowing dates and varieties for days to head formation and head harvest were earlier reported by Sharma (2001), Singh *et al*. (2010) and Zagade *et al*. (2010).

5.1.3 Head characters

Among the different sowing dates, November 1st sowing recorded highest head depth (10.67 cm) and head diameter (10.45 cm). This may be due to better vegetative growth for the plants sown in November 1st resulting in good heads by the favourable weather prevailed during the period. Nilsson (1988) reported that head and core carbohydrate levels responded differently to solar radiation, temperature and degree days. Also heaxose, sucrose and total sugar levels correlated more strongly with degree days over the whole growing cycle than with conditions within two weeks of harvest at crop maturity. It is suggested that cumulative environmental conditions prevailed in the early crop growth and development stage resulted in specific head and core traits in cabbage.

Head characters like head depth and head diameter were highest for NS 183 and New Orient. Lowest were recorded for Red C- 05 and Gayatri. Earlier findings for variability among genotypes for head characters were reported by Kleinhenz and Wszelaki (2003), Adenji *et al*, (2009), Hasan and Solaiman (2012), Richardson (2012).

Among interaction effects, maximum head depth and head diameter were observed in November 1st sowing of NS 183 and New Orient. Studies by Kleinhenz and Wszelaki (2003) and Adenji *et al*, (2009) support the present findings. For core length, lowest value was recorded for November 1st sowing of Indam Radha.

Head solidity / head compactness is a preferred head character in cabbage and expressed as an index. Head compactness is very important parameter which is directly associated with transportability, marketability, shelf life and consumers preference. Pearson (1931) had explained this index as the ratio of net head weight and cube of mean head depth and diameter. In the present investigation, some of the varieties formed small shaped heads which in turn resulted in high solidity. Small heads resulted in high compactness value since they had low net head weight, head depth and head diameter. This is in line with the earlier findings of Singh *et al*. (2010).

High solidity value was observed in Red C- 05 which produced small heads and low for Summer Cross, Asia cross and New orient which produced normal heads. This is in agreement with the earlier findings of Crevenski *et al. (*1998) and Wszelaki and Keleinhenz (2003).

In the present study highest solidity was obtained for November 1st and October 1st sowing of Red C- 05. Minimum was recorded in Summer Cross and Indam Radha. Similar results were reported by Crevenski *et al.* (2012).

In this study the character head core length was not influenced by sowing date. This was in accordance with the finding of Keleinhenz and Wszelaki (2003) Least core length was observed for Veer – 333, Indam Radha, Asia Cross and Gayatri. Varietal difference for core length in cabbage was reported by Adzic *et al*. (2012). Interaction effect showed that least core length was obtained for the above varieties sown on November 1st.

5.1.4 Yield characters

Yield is the most important factor in any crop production. In cabbage, head is the economic part and the net head weight was found to be influenced by different sowing dates. It was highest for November 1st sowing (519.03 g) followed by that of October 15th (451.21 g) and the minimum was noticed in October 1st (306.13 g). It was clear from the result that in southern Kerala a difference of 15 days in sowing resulted in remarkable reduction in head yield. This in accordance with the findings of Hara *et al.* (1981), Hara and Sonoda (1982) in cabbage and Pradeepkumar *et al*. (2002) and Karthika *et al*. (2013) in cauliflower. Seasonal variation in environmental conditions affect the head formation of cabbage plant. Among the environmental factors temperature is the most influential through its effect on the carbohydrate production and consumption by the plant. Cabbage head development is efficient only when the outer leaves have a carbohydrate/nitrogen content ratio (C/N ratio) of about 7-10 and a nitrogen content of about 2-3 % (Hara and Sonoda, 1982). Decreases in the cabbage head yield and carbohydrate content in cabbage may be due to the presence of high temperature and the consumption of carbohydrate for respiration.

Similarly gross head weight, harvest index and yield per plot were high for November 1st sowing. This in accordance with the finding of Everaarts and Moel (1998), Futane *et al.* (1995), Sharma (2001) and Radovich *et al.* (2005).

Among varieties, the best performers with respect to net head weight, gross head weight and yield per plot were New Orient and NS 183 whereas Gayatri and Red C-05 were poor yielders. The present result is in accordance with the finding of Narayanankutty *et al.* (2012) who identified NS 183 as the suitable variety for the warm humid tropics of Kerala. Variability among genotypes for yield were reported by several workers conforming the present findings Bhardwaj (1996), kumar (1998), Gopalakrishnan (2004), Adenji *et al.* (2009) and Kumar *et al.* (2013).

Harvest index gives an indication about the extent of economic yield to total biological yield. In the present study it was high for New Orient and NS 183 and low for Red C-05 and Indam Radha.

The interaction of November 1st sowing of New Orient and NS 183 resulted in highest net head weight (876.67 g & 851.33 g), gross head weight (922.67 g & 884.33 g), harvest index (0.67 & 0.64) and yield per plot (21.91 kg & 21.28 kg) respectively. Similar higher yield was reported by several workers conforming to the present findings of Futane et *al.* (1995), Everaarts and Moel (1998), Sharma (2001), Adenji *et al.* (2009) and Singh *et al.* (2010).

5.1.5 Quality characters

Quality characters are as important as yield in food crops especially vegetables. But in most of the cases quality is negatively correlated with yield. In the present study, it was observed that protein, Vitamin A and vitamin C content were highly influenced by genotype rather than environment. Contrary to the present findings, variation in quality characters under varying environmental conditions was earlier reported by JiaFu (2005).

Among the varieties high protein and Vitamin C content was observed in Red C-05. New Orient recorded high vitamin A content among varieties. Variation among cabbage genotypes for protein, vitamin C and vitamin A were reported by Cebula *et al.* (1996), Znidarcic *et al.* (2007), Singh *et al.*(2010) and Meena *et al.* (2012).

Plate 5. Top yielders

New Orient

NS 183

Significant interactions between sowing dates and varieties were observed for protein, Vitamin A and Vitamin C content. New Orient and Red C- 05 sown on November 1st had high protein, Vitamin A and Vitamin C content respectively. This in accordance with the finding of Cebula *et al.* (1996) and Singh *et al.* (2010).

5.1.6 Physiological disorders

Physiological disorders of cole crops occur as a result of environmental stress, nutritional deficiencies or excesses on the plants. In the present study, incidence of physiological disorders was minimum. Physiological disorders observed in the study were multiple head / blindness and burst head. It was observed only in October 1st and November 15th sowing. This is in agreement with the earlier findings of Masarirambi *et al.* (2011).

Among the varieties burst head disorder were observed in varieties like Gayatri, Summer Cross, Indam 1299, Asia Cross and BC-38.

Interaction effects varied significantly and incidence of multiple head and burst head were found only in Gayatri, Summer Cross, Indam 1299, Asia Cross and BC-38 sown on October 1st and November 15th.

5.1.7 Pests and diseases

Temperature, rainfall and relative humidity are the critical climatic factors that have profound effect on incidence of pests and diseases. The above condition influences the activity and seasonal population dynamics of insects (Roy *et al.*, 2002) and it provides a congenial condition for fungal pathogen causing diseases. Similar situation was experienced in the present study also.

During the course of the study, the important biotic stress factors noticed were leaf caterpillar (*Spodoptera litura*), rhizoctonia blight (*Rhiaoctonia solani*), alternaria leaf spot and head rot (*Alternaria brassicae*). Least incidence was observed in November 1st sowing, since the active vegetative period and heading time coincided with low temperature, rainfall and relative humidity.

High incidence of pests and diseases like leaf caterpillar, alternaria leaf spot, head rot and rhizoctonia blight were observed for certain treatments during the period. Among the varieties low incidence of these pests and diseases were noticed in NS 183, New Orient, Veer- 333 and Red C-05. Various workers have reported incidence of the above pests and diseases in cabbage i.e., leaf caterpillar (*Spodoptera litura*) by Soujanya *et al.* (2004), leaf spot caused by *Alternaria brassicae* by Kucharek, (2000) and Mehta *et al*. (2005).

Low incidence of leaf caterpillar, alternaria leaf spot, head rot and rhizoctonia blight were observed in November 1st sowing of NS 183, New Orient, Veer- 333 and Red C-05.

5.1.8 Morphological characters

Almost all the varieties *viz*., NS 183, Gayatri, Veer-333, Indam 296, Indam Radha, Indam 1299 and Red C- 05 had erect leaf which contributes to self blanching character and hence mostly preferred. The varieties Summer Cross, New Orient, Asia Cross and BC- 38 are with semi erect leaves. The varieties NS 183 and Indam 296 had round shaped heads while Summer Cross, New Orient, Asia Cross and BC- 38 had flat heads. Round and flat shaped heads are more preferred in cabbage.

5.1.9 Influence of weather parameters

When a cabbage plant grows, it first increases the number of wrapper leaves and extends the area of each leaf. Second, it starts to express head formation in middle of the developmental stage and finally forms a mature head with adequate size and density by increasing the number and weight of the head leaves during continuous vegetative growth. These developmental processes indicate that developmental characteristics in vegetative growth are more important as a continuous process for cabbage maturation (Tanaka and Niikura, 2003). According to Hara and Sonoda (1982) in cabbage among the environment factors, temperature is the most influential factor through its effect on the carbohydrate production and consumption of plants. The decrease in cabbage head yield may be due to the genetically susceptibility of cabbage plant to high temperature and consumption of carbohydrates for respiration. The respiration for maintenance of plants increases with a high temperature and low light intensity and loss of carbohydrates for respiration occurs, resulting in decrease in the carbohydrate content. So the temperature higher than 25^0C will result in reduced development of cabbage heads and spoil their quality.

Temperature had a significant effect on cabbage head shape as average head length / width ratio is higher in favourable temperature. Temperature, growing degree-day accumulation and solar radiation influence cabbage head and core traits (Nilsson, 1988). Average daily temperature during main periods of crop development (pre heading and head formation) affected head development in cabbage.

In the present study, the crop gave better yield when the minimum and maximum temperature during head initiation stage was 20.8^{o}C and 30.6^{o}C respectively which coincided with the November 1st sowing. This is in accordance with the findings of Narayanankutty *et al.* (2012) who reported that an average day temperature of 28-32 ^{0}C and night temperature of 19- 22^{0}C is favourable for cultivation of cabbage in the plains of Kerala.

Lowest yield was recorded in October 1st sowing. The rainfall occurred after head initiation resulted in damage of head due to incidence of head rot, rhizoctonia blight and alternaria leaf spot lead to yield loss in cabbage for the October 1st sowing.

5.2 Variability studies

The magnitude of variability present in a population is of utmost importance as it provides the basis for effective selection. Since the observed variability in a population is the sum of variation arising due to the genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential. The PCV and GCV are the components used to measure the variability present in a population.

In the present investigation, the phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all the traits, which indicates that the genotypic expression was super-imposed by the environmental influence. Such environmental interference in the manifestation of these characters was earlier reported by Jamwal *et al.* (1992).

The PCV and GCV were highest for gross plant weight, net head weight, gross head weight and yield per plot. Similar findings were also reported by Kumar (1998), Sharma (2001), Sharma (2007), Atter *et al*. (2009) and Singh *et al.* (2011). For selection of such characters, therefore, more vigorous testing of progenies over different environments may be required.

High and closer estimates of phenotypic and genotypic coefficients of variation were observed for gross plant weight, head and yield characters suggesting greater contribution of genotype rather than environment. These results were in line with Atter *et al.* (2009) and Singh *et al.* (2011).

In the case of quality characters vitamin C content recorded highest phenotypic and genotypic coefficient of variation. This is in accordance with the findings of Meena *et al.* (2012).

High magnitude of PCV, GCV and their difference for incidence of physiological disorders like burst head, multiple head / blindness and incidence of pests and diseases like leaf caterpillar, alternaria leaf spot, rhizoctonia blight and head rot were observed.

From the foregoing discussions, it is clear that the characters *viz*., gross plant weight, net head weight, gross head weight, harvest index offer good scope for improvement through selection in cabbage.

5.3 Heritability and genetic advance

The variability existing in a population is the sum total of heritable and non heritable components. A high value of heritability indicates that the phenotype of that trait strongly reflects its genotype. The magnitude of heritability indicates the effectiveness with which selection of the genotypes can be made based on the phenotype.

In the present investigation, the heritability estimates were high for all characters studied except for Vitamin A content and incidence of burst head, multiple head, leaf caterpillar, rhizoctonia blight and head rot which have least heritability. High heritability can be attributed to the greater role of additive gene and additive x additive gene action, which can be exploited by following simple selection. Similar reports have also been put forward by Singh *et al.* (1995) and Reddy and Varalakshmi (1995). High heritability for yield and yield attributes in cabbage was reported by many workers earlier (Bhardwraj, 1996; Sharma, 2001; Kumar, 2004; Meena *et al.,* 2009; Antonova, 2009; Singh *et al.,* 2011; Meena *et al*., 2012).

Singh *et al.* (2011) observed high heritability for plant height and non wrapper leaves per plant (94.3 & 91.6%) in cabbage. High heritability for days to head maturity was reported by Bhardwraj (1996) and for core length and head solidity by Atter *et al.* (2009) and Singh *et al.* (2011)

High heritability estimates indicate the effectiveness of selection based on good phenotypic performance but does not necessarily mean high genetic gain for the particular character. Johnson *et al*. (1955) pointed out that high heritability along with high genetic advance would be useful than heritability values alone in predicting the resultant effect of selecting the genotype.

High values of genetic advance as percentage of mean (> 20 %) were obtained in the present study for plant height, gross plant weight, leaf length, leaf breadth, leaf size, days to head formation, days to head harvest, days to head maturity, head depth, head diameter, core length, net head weight, gross head weight, harvest index and yield per plot. The results are in line with the findings of Atter *et al.* (2009) and Singh *et al.* (2011). On the other hand, Sharma (2007) reported high genetic advance for head compactness which is contradictory to the present findings where in compactness exhibited low genetic advance. Biochemical characters like Vitamin C content showed high genetic advance whereas, Vitamin A content had low genetic advance.

In the present study net head weight, gross head weight, harvest index, gross plant weight, plant height, leaf size, days to head formation, days to head harvest, days to head maturity, head depth, head diameter and core length recorded high heritability coupled with high genetic advance indicating the presence of flexible additive gene effects and will be a useful criterion for selection for these characters. This result confirms the findings of Bhardwraj (1996), Atter *et al.* (2009) and Singh *et al.* (2011) who reported high heritability coupled with high genetic advance for whole plant weight, non wrapper leaves per plant, gross head weight, net head weight and core length. High heritability and low genetic advance observed for non wrapper leaves per plant and head compactness in the present study is in accordance with the findings of Sharma (2007) and Singh *et al*. (2011).

Low heritability coupled with low genetic advance was observed for vitamin A content whereas high heritability coupled with high genetic advance was observed for Vitamin C and protein content.

5.4 Correlation Studies

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Correlation provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection for a particular character, not only it improves that trait, but also provides a reliable measure of genetic association between them, which is useful in the breeding programmes.

In the present study, high and positive phenotypic and genotypic correlation was obtained between net head weight and non wrapper leaves per plant, leaf size, gross plant weight, head depth, head diameter, harvest index and yield per plot. It exhibited significant negative correlation with days to head formation, days to head harvest, days to head maturity and head solidity.

Positive genotypic correlation of net head weight with plant height, non wrapper leaves per plant, leaf size, gross plant weight, head diameter, gross head weight, harvest index was in line with the results reported by Bhardwaj (1996), Sharma (2001), Abbey and Manso (2004), Sharma (2007), Kumar *et al.* (2007) and Adzic *et al.* (2012).

According to Kumar (1998), Kumar *et al.* (2007) and Singh *et al.* (2010) net head weight was negatively correlated with head compactness which was in line with the findings of present study. On the other hand, Cervenski *et al.* (1998), Sharma (2001), Sharma (2007), Cervenski *et al.* (2012) reported that head compactness was positively correlated with net head weight which was contrary to the present findings.

Positive correlations between net head weight and head depth and head diameter was reported by Abbey and Manso (2004), Antonova (2009) and Adzic *et al.* (2012) which was in accordance with the present findings.

Positive correlations between net head weight and core length was reported by Bhardwaj (1996) and Singh *et al.* (2010) which was in line with the findings of present study.

Singh *et al.* (2010) observed negative correlation of days to head maturity on net head weight which was in conformity with the present findings while the findings of Sharma (2007) and Kumar *et al.* (2007) were against the above result.

Positive and high phenotypic and genotypic correlation of net head weight with other characters implies that these characters can be taken into consideration for indirect selection for yield improvement in cabbage.

5.5 Path analysis

The path analysis unravels whether the association of the component characters with yield is due to their direct effect on yield, or is a consequence of their indirect effect via some other trait(s). Thus path analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effects of the component characters on the yield on the basis of which improvement programmes can be devised effectively. If the correlation between yield and any of its components is due to the direct effect, it reflects a true relation between them and selection can be practiced for such a character in order to improve yield. But if the correlation is mainly due to indirect effect of the character another component trait, the breeder has to select the latter trait through which the indirect effect is exerted.

In the present study leaf size, non wrapper leaves per plant and core length showed positive direct effect on net head weight. This is in line with the findings of Bhardwaj (1996), Sharma (2001) and Singh *et al.* (2010).

Days to head formation, days to head harvest and head solidity had negative direct effect on net head weight. This is in line with the findings of Singh *et al.* (2010). Contrary to the present findings, Kumar (1998) and Sharma (2007) reported that head compactness had positive direct effect on yield.

5.6 Selection index

Discriminant function analysis developed by Fisher (1936) gives information on the proportionate weight age to be given to a yield component. Thus, selection index was formulated to increase the efficiency of selection by taking into account the important characters contributing to yield. Further Hazel (1943) suggested that selection based on suitable index was more efficient than individual selection for the characters.

The characters used for constructing selection index were plant height, non wrapper leaves per plant, leaf size, days to head formation, days to head harvest, days to maturity, head depth, head diameter, head solidity, net head weight, gross head weight, harvest index, protein, vitamin A and vitamin C. Based on the selection index values, top ranking varieties were New Orient (11747.35), NS 183 (9539.32), BC- 38 (9064.22), Asia Cross (8152.67) and Summer Cross (6779.98). They were identified as superior ones in terms of head and yield characters.

The results of the present study identified two varieties of cabbage namely New Orient and NS 183 as promising and the most ideal time of sowing as November 1st for better yield and quality for southern parts of Kerala.

SUMMARY

6. SUMMARY

The study entitled "Evaluation of cabbage **(***Brassica oleracea* L. var. *capitata*) for southern Kerala" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period October 2012 to March 2013. The main objective of the experiment was the identification of tropical cabbage varieties suitable for plains of southern Kerala and to study the influence of date of sowing and their interactions on yield and quality.

The experiment was laid out in split plot design with four sowing dates as main plot treatment and 11 varieties of cabbage as the subplot treatments constituting forty four treatments with five replications. The sowing dates were 1^{st} October, 15^{th} October, 1^{st} November and 15^{th} November. The 11 varieties were Summer Cross, New Orient, Gayatri, Veer-333, Indam 296, Indam Radha, Indam 1299, NS 183, BC – 38, Asia Cross and Red C-05.

Observations were recorded on important vegetative, head and yield characters. The data generated were analysed, presented in tables and discussed in previous chapters. Genetic analysis was also carried out. The findings of the study are summarised below.

- The direct effect of the treatments showed that highest plant height was for November 1^{st} sowing and the variety, Red C-05. The interaction effect revealed that highest plant height was for Red C-05 sown on November 1^{st}.

- Maximum non wrapper leaves per plant was recorded by November 1^{st} sowing and Red C-05. D x T interaction showed that BC- 38 sown on November 1^{st} had maximum non wrapper leaves per plant.

- November 1^{st} sowing recorded highest gross plant weight and among varieties it was for New Orient. Interaction effect showed that maximum gross plant weight was for NS 183 sown on November1^{st}.

- Leaf length, breadth and size were significantly influenced by different sowing dates and varieties. November 1st recorded maximum values for these characters and among varieties, New Orient was the best. Interaction effect revealed that November 1st sowing of New Orient was superior for leaf length, breadth and size.

- Sowing on November 1st resulted in earliest head formation. Among varieties, New Orient followed by NS 183 was the earliest. D x T interactions showed that November 1st sowing of NS 183 (40.23 days) and New Orient (40.53 days) were earlier.

- Earliest head harvest was for November 1st sowing and among varieties NS 183 (67.33 days) and New Orient (60.72 days). Interaction effect was significant and November 1st sowing of New Orient and NS 183 resulted in early head harvest.

- Minimum days for head maturity were observed in November 1st sowing. Among varieties NS 183 followed by New Orient was the earliest. Interaction effects showed that November 1st sowing of NS 183 resulted in early maturity.

- November 1st sowing resulted in maximum head depth and head diameter. Among varieties, New Orient and NS 183 were superior for these characters. Interaction effect showed that November 1st sowing of New Orient and NS 183 had maximum head depth and head diameter.

- Head solidity was not significantly influenced by date of sowing. High solidity was observed for Red C-05. D x T interaction was highest for November 1st sowing of Red C-05.

- November 1st sowing resulted in minimum core length. Among varieties Veer-333 was superior. D x T interaction showed that November 1st sowing of Indam Radha resulted in least core length.

- The most important character, the net head weight was influenced by different sowing dates and varieties. November 1st sowing resulted in maximum (519.03 g) net head weight. It was highest for New Orient (645 g) followed by NS 183 (614.83 g). Among the interaction effects November 1st sowing of New Orient (876.67 g) followed by NS 183 (851.33 g) recorded highest net head weight.

- Gross head weight was also influenced by different sowing dates and varieties. November 1st sowing resulted in maximum gross head weight. It was highest for New Orient followed by NS 183. Interaction effects showed that highest gross head weight was obtained for November 1st sowing of New Orient and NS 183.

- Highest harvest index was recorded by November 1st sowing. Among the varieties it was highest for New Orient and NS 183. Interaction effects showed that November 1st sowing of New Orient and NS 183 was the best for these characters.

- Yield per plot revealed that November 1st sowing was the best. New Orient and NS 183 were the top yielders. The interaction effects showed that New Orient and NS 183 sown on November 1st resulted in highest yield.

- There was no significant difference between sowing dates for protein, vitamin A and vitamin C content whereas, varietal influence was significant. Among varieties Red C-05 recorded highest protein and vitamin C content. New Orient had highest Vitamin A content. The interaction effects showed that maximum protein and vitamin C content was recorded for Red C-05 in all the sowing dates, while maximum vitamin A content was recorded in November 1st sowing of New Orient.

- November 1st and October 15th sowing recorded lowest incidence of all physiological disorders like multiple head and blindness. Varietal difference and interaction effects were also significant.

- Incidence of pest like leaf caterpillar (*Spodoptera litura*) and diseases like *Alternaria* leaf spot, *Rhizoctonia* blight and head rot differs significantly among sowing dates, varieties and their interactions.

- Phenotypic and genotypic coefficients of variation were high for gross plant weight, net head weight, gross head weight, yield per plot, incidence of physiological disorders, pests and diseases.

- Heritability along with genetic advance were high for gross plant weight, leaf size, days to head formation, days to head harvest, days to head maturity, head depth, head diameter, core length, net head weight, gross head weight, harvest index and yield per plot.

- At genotypic level net head weight showed high positive correlation with plant height, non wrapper leaves per plant, gross plant weight, leaf size, head diameter and core length.

- Path coefficient analysis revealed that non wrapper leaves per plant, leaf size and core length had high positive direct effect on yield.

- Selection index was worked out and the top ranking varieties were New Orient, NS 183, BC- 38 and Asia Cross.

- The present study identified two high yielding varieties namely New Orient and NS 183 as promising and November 1st sowing as the best sowing time for cultivation in southern Kerala.

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APPENDICES

APPENDIX – I

Descriptor for cabbage

1 Seedling leaf colour

1 White green
2 Yellow green
3 Light green
4 Green
5 Dark green
6 Purple green
7 Purple
8 Other

2. Seedling leaf margin serration

0 No serration
1 Crenate
2 Dentate
3 Doubly dentate
4 Other

3. Position of leaves

3 Erect
5 Semi-erect
7 Prostrate

4. Shape of leaf blade

1 Elliptic
2 Broad ovate
3 Circular
4 Transverse broad
5 Obovate

5. Leaf colour

1 Yellow green
2 Green
3 Grey green
4 Blue green
5 Violet

6. Leaf waxiness

1 Absent or very weak
3 Weak
5 Medium
7 Strong
9 Very strong

APPENDIX – I Continued

7. Undulation of leaf magrin

   1 Absent or very weak

   3 Weak

   5 Medium

   7 Strong

   9 Very strong

8. Shape of head

   1 Round

   2 Elliptical

   3 Flat

   4 Obovate

   5 Oblong

   6 Cylindrical

   7 Others

9. Head: shape in longitudinal section

   1 Transverse narrow elliptic

   2 Transverse elliptic

   3 Circular

   4 Broad elliptic

   5 Broad obviate

   6 Broad ovate

   7 Angular ovate

10. Head : shape of base in longitudinal section

   1 Round

   2 Flat

   3 Arched

11. Head length

   3 Short

   5 Medium

   7 Long

APPENDIX – I Continued

12. Head diameter

3 Small

5 Medium

7 Large

13. Head: position of maximum diameter

1 Towards top

2 At middle

3 Towards top

14. Head cover

1 not covered

2 partially covered

3 Covered

7 Strong

8 Very Srong

15. Head: anthocyanin colouration of cover leaf

1 Absent or very week

3 Weak

5 Medium

16. Head internal colour

1 Whitish

2 Yellowish

3 Greenish

4 Violet

17. Head density

1 Very loose

3 Loose

5 Medium

7 Dense

9 Very dense

18. Head internal structure

3 Fine

5 Medium

7 Coarse

APPENDIX - II

Weather data for the cropping period

(Oct 2012 to March 2013)

Standard week	Temperature (°C) (maximum)	Temperature (°C) (minimum)	Rainfall (mm)	Relative Humidity (%)
40	31.2	23.5	0.0	89.6
41	31.4	24.1	6.3	90.3
42	29.4	23.4	10.7	94.4
43	30.1	23.9	7.5	94.6
44	29.8	23.3	12.5	91.9
45	30.1	23.0	15.8	96.9
46	30.3	23.2	3.0	95.6
47	30.5	23.1	1.0	98.6
48	30.6	22.7	0.0	99.0
49	30.5	22.6	0.5	99.0
50	30.6	22.1	0.0	99.0
51	31.1	22.8	0.0	91.4
52	30.5	23.5	13.3	99.0
1	30.6	23.4	8.8	95.4
2	30.0	22.6	24.0	96.4
3	30.1	20.8	0.0	96.0
4	30.5	21.3	0.0	96.1
5	30.4	20.8	0.0	94.3
6	31.2	22.9	2.5	93.3
7	32.0	23.0	11.0	92.4
8	31.4	21.8	0.0	89.9
9	32.0	21.4	0.0	91.3
10	32.1	24.3	7.0	94.7
11	32.3	23.9	34.0	93.4
12	32.3	23.7	0.0	91.4
13	32.5	23.3	31.0	92.7

EVALUATION OF CABBAGE (*Brassica oleracea* L. var. *capitata)* FOR SOUTHERN KERALA

DIVYA. P

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Abstract of the

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ABSTRACT

The experiment entitled “Evaluation of cabbage (*Brassica oleracea* L.var.*capitata*) for southern Kerala” was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during 2012-2013. The objectives were to identify tropical cabbage varieties suitable for plains of southern Kerala and to study the influence of date of sowing on yield and quality.

The experiment was laid out in the field in split plot design with four dates of sowing as main plot and 11 varieties of cabbage as sub plot treatments with five replications.

Analysis of variance revealed significant difference among sowing dates, varieties and their interactions for all the characters studied.

Among the four different sowing dates (October 1st, October 15th, November 1st and November 15th), November 1st sowing recorded best yield characters. Highest yield (net head weight) was recorded for November 1st sowing (519.03 g) followed by October 15th sowing (451.21 g). Sowing on November 1st resulted in early head formation and early head harvest. Better gross plant weight, non wrapper leaves per plant, leaf length, leaf breadth and leaf size were also observed in November 1st sowing. No significant differences were observed for head solidity, core length and quality characters like protein, vitamin A and vitamin C between different sowing dates. Least incidence of physiological disorders, pest and diseases were observed on November 1st sowing.

Among the varieties, New Orient (645g) and NS 183 (614.83g) were the highest yielders. Head depth and head diameter were highest for NS 183 followed by New Orient. Earliest among the varieties was New Orient followed by NS 183 and the late variety was Red C-05. Significant differences were observed among varieties for all quality characters. Red C-05 had maximum protein (1.12%) and vitamin C (70.97 mg/100g).

The interaction effects were significant for all the characters studied. Yield characters were best for New Orient (876.67 g) and NS 183 (851.33g) sown on November 1^{st}. November 1^{st} sowing of Red C-05 recorded maximum head solidity. New Orient recorded highest gross plant weight, leaf length and leaf size where as Indam 296 sown on October 15^{th} recorded minimum non wrapper leaves per plant. Maximum protein and vitamin C content were recorded for Red C-05 sown on November 1^{st} whereas New Orient sown on same date recorded highest vitamin A. Least incidence of physiological disorders, pest and diseases were observed on November 1^{st} sowing.

Variability among genotypes for all the characters was studied using phenotypic and genotypic coefficient of variation, heritability and genetic advance. High phenotypic coefficient of variation and genotypic coefficient of variation were observed in net head weight, gross head weight, gross plant weight and head diameter. High heritability and high genetic advance was also observed for these characters. The path analysis revealed that leaf size, non wrapper leaves and core length had direct effect on yield. Correlation studies revealed that plant height, gross plant weight, head diameter, core length, head depth and non wrapper leaves had high positive correlation on yield.

Selection index values were calculated based on discriminant function analysis and found that New Orient was best followed by NS-183.

The present study identified two high yielding varieties namely New Orient and NS 183 as promising and November 1^{st} sowing as the best sowing time for cultivation in southern Kerala.

സംഗ്രഹം

"ദക്ഷിണ കേരളത്തിനു അനുയോജ്യമായ ക്യാബേജന്റെ (ബ്രാസ്സിക്ക ഒളറേസ്യ ഇനം ക്യപിറ്റേറ്റ) മൂല്യനിർണയം''എന്ന നിരീക്ഷണം വെള്ളായണി കാർഷിക കോളേജിലെ ഒളരിക്കൾച്ചർ വിഭാഗത്തിൽ ഒക്ടോബർ 2012 മുതൽ മാർച്ച് 2013 വരെയുള്ള കാലഘട്ടത്തിൽ നടത്തി.

ദക്ഷിണ കേരളത്തിലെ സമതല പ്രദേശങ്ങൾക്കനുയോജ്യമായ ക്യാബേജ് ഇനങ്ങൾ തിരിച്ചറിയുക എന്നതും നടീൽ സമയത്തിനു ആദായത്തിലും ഗുണത്തിലുമുള്ള സ്വാധീനം മനസ്സിലാക്കുക എന്നതുമായിരുന്നു ഈ പഠനത്തിന്റെ ഉദ്ദേശ്യം.

നാല് നടീൽ സമയം മുഖ്യ കണ്ടത്തിലും 11 ക്യാബേജ് ഇനങ്ങൾ കീഴ് കണ്ടത്തിലും എന്ന രീതിയിൽ അഞ്ചു ആവർത്തനങ്ങളായി സ്പ്ലിററ് പ്ലോട്ട് രൂപരേഖയിലാണ് ഈ പരീക്ഷണം നടത്തിയത്.

നടീൽ സമയവും ക്യാബേജ് ഇനങ്ങളും അവയുടെ പരസ്പര പ്രവർത്തനങ്ങളും തമ്മിലുള്ള വ്യത്യസ്തതയുടെ അപഗ്രഥനം ഇവയിലുള്ള പ്രബലമായ വ്യത്യാസത്തെ സൂചിപ്പിച്ചു.

നവംബർ ഒന്നാം തീയതി വിത്ത് പാകിയ ചെടികളിൽ നിന്നും നല്ല വിളവു ലഭിച്ചതായി നിരീക്ഷണത്തിലൂടെ കണ്ടെത്തി. ഏറ്റവും വലിയ ക്യാബേജ് ഹെഡുകൾ നവംബർ ഒന്നാം തീയതി പാകിയ ചെടികളിലും (519.03 ഗ്രാം) തുടർന്ന് ഒക്ടോബർ പതിനഞ്ചാം തീയതി പാകിയ ചെടികളിലും (451.21 ഗ്രാം) നിന്നു ലഭിച്ചു. നവംബർ ഒന്നാം തീയതി പാകിയ ചെടികളുടെ ഉയരം, ഭാരം, ഇലകളുടെ എണ്ണം, വിസ്തീർണ്ണം എന്നിവ കൂടുതലായി കണ്ടു. മാംസ്യം, ജീവകം എ, സി എന്നിവയുടെ അളവിൽ വിത്ത് പാകുന്ന സമയമനുസരിച്ച് പ്രബലമായ യാതൊരു വ്യത്യാസവും കണ്ടെത്താനായില്ല. എന്നാൽ നവംബർ ഒന്നാം തീയതി പാകിയ ചെടികളിൽ കീടരോഗങ്ങൾ നന്നേ കുറവായതായി കാണപ്പെട്ടു.

ഹെഡിന്റെ തൂക്കം, നീളം, വീതി, വലുപ്പം എന്നിവയിൽ ന്യൂ ഓറിയന്റ്, NS 183 എന്നീ ഇനങ്ങൾ മുന്നിലായി കണ്ടു. ന്യൂ ഓറിയന്റ്, NS 183 എന്നി ഇനങ്ങളിലാണ് ആദ്യം ഹെഡ് ഉണ്ടായത് . മാംസ്യം, ജീവകം എ, സി എന്നിവയുടെ അളവിൽ ഇനങ്ങൾ തമ്മിൽ പ്രബലമായ വ്യത്യാസം ഉള്ളതായി കണ്ടെത്തി. റെഡ് സി-05 എന്ന ഇനത്തിൽ മാംസ്യവും (1.12%) ജീവകം സി (70.97 mg/100g) കൂടുതലായി കാണപ്പെട്ടു.

വിത്ത് പാകുന്ന സമയവും ക്യാബേജ് ഇനങ്ങളും തമ്മിലുള്ള പാരസ്പര്യബന്ധത്തിലും പ്രബലമായ വ്യത്യാസങ്ങൾ കണ്ടെത്താനായി. നവംബർ ഒന്നാം തീയതി വിത്ത് പാകിയ ന്യൂ ഓറിയന്റ് (876.67 ഗ്രാം), NS 183 (851.33 ഗ്രാം) എന്ന ഇനങ്ങൾ ആദായത്തിലും ഗുണത്തിലും മികച്ചു നിന്നു. നവംബർ ഒന്നാം തീയതി വിത്ത് പാകിയ ന്യൂ ഓറിയന്റ് എന്ന ഇനത്തിലാണ് ഉയരം, ഭാരം, ഇലകളുടെ എണ്ണം, വിസ്തീർണ്ണം എന്നിവ കൂടുതലായി കാണപ്പെട്ടത്. നവംബർ ഒന്നാം തീയതി വിത്ത് പാകിയ റെഡ് സി-05 ഇനത്തിലാണ് മാംസ്യവും ജീവകം സിയും കൂടുതലായി

കാണപ്പെട്ടത്. എന്നാൽ ജീവകം എ കൂടുതലായി കാണപ്പെട്ടതു ന്യൂ ഓറിയന്റ് എന്ന ഇനത്തിലാണ്. നവംബർ ഒന്നാം തീയതി പാകിയ ചെടികളിൽ കീടരോഗങ്ങൾ നന്നേ കുറവായതായി കാണപ്പെട്ടു.

ക്യാബേജ് ഇനങ്ങളുടെ വ്യത്യസ്തതാ പഠനത്തിനായി കോഎഫിഷ്യന്റ് ഓഫ് വേരിയേഷൻ, ഹെറിറ്റബിലിറ്റി, ജെനറ്റിക്ക് അഡ്വാൻസ്, കോറിലേഷൻ, പാത്ത് അനാലിസിസ്, സെലക്ഷൻ ഇൻഡക്സ് തുടങ്ങിയ രിതികൾ അവലംബിച്ചു . ഇതിലൂടെ ചെടിയുടെ നീളം, ചെടിയുടെ ഭാരം, ഹെഡിന്റെ ആഴം, വീതി, കോറിന്റെ നീളം എന്നിവ ആദായവുമായി അനുബന്ധപ്പെട്ടിരിക്കുന്നതായി കണ്ടെത്തി.

ഈ നിരിഷണത്തിലൂടെ ന്യൂ ഓറിയന്റ്, NS 183 എന്നീ ഇനങ്ങൾ ദക്ഷിണ കേരളത്തിലെ സമതലങ്ങളിൽ ക്യാബേജ് കൃഷിക്ക് അനുയോജ്യമാണെന്നും നവംബർ ഒന്നാം തീയതി വിത്ത് പാകാൻ യോജിച്ച സമയമാണെന്നും കണ്ടെത്തി.