PERFORMANCE OF CHINESE CABBAGE HYBRIDS UNDER VARIOUS GROWING CONDITIONS

by

Mr. Shreerama T.
(Reg. No. K-19/317)

HORTICULTURE SECTION

RAJARSHEE CHHATRAPATI SHAHU MAHARAJ COLLEGE OF AGRICULTURE, KOLHAPUR

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413722, DIST-AHMEDNAGAR
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A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI- 413 722, DIST- AHMEDNAGAR,
MAHARASHTRA, INDIA

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

VEGETABLE SCIENCE

HORTICULTURE SECTION

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APPROVED BY

Dr. M. D. Mali
(Chairman and Research Guide)

Dr. B. T. Patil
(Committee Member)

Dr. S. S. Dhumal
(Committee Member)

Prof. V. R. Bavadekar
(Committee Member)

HORTICULTURE SECTION

RAJARSHEE CHHATRAPATI SHAHU MAHARAJ
COLLEGE OF AGRICULTURE, KOLHAPUR

MAHATMA PHULE KRISHI VIDYAPEETH
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2021

CANDIDATE'S DECLARATION

I hereby declare that, this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

Place : Kolhapur (Shreerama T.)

Date : / /2021

Dr. M. D. Mali
Officer Incharge, TRS
&
Assistant Professor of Horticulture,
Agril. Research Station, K. Digraj, Sangli
Maharashtra, India

CERTIFICATE

This is to certify that, the thesis entitled **"PERFORMANCE OF CHINESE CABBAGE HYBRIDS UNDER VARIOUS GROWING CONDITIONS"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE**, embodies the results of a piece of bonafide research work carried out by **Mr. SHREERAMA T.** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place : Kolhapur (M. D. Mali)
Date : / /2021

Dr. S. S. Dhumal
M.Sc. (Agri), Ph.D. (Hort), PDF (MSU, USA),
ACP (Food laws), PGD (Geoinformatics),
PGDAEM (Manage, Hyderabad), FSASS
Professor of Horticulture (I/c)
Rajarshee Chhatrapati Shahu Maharaj
College of Agriculture, Kolhapur-416004
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413722, Dist- Ahmednagar,
Maharashtra, India

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Place : Kolhapur (S. S. Dhumal)
Date : / /2021

Dr. U. B. Hole
Associate Dean,
Rajarshee Chhatrapati Shahu Maharaj
College of Agriculture, Kolhapur-416004
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413722, Dist- Ahmednagar,
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Place : Kolhapur (U. B. Hole)
Date : / /2021

ABSTRACT

PERFORMANCE OF CHINESE CABBAGE HYBRIDS UNDER VARIOUS GROWING CONDITIONS

By

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A candidate for the degree

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HORTICULTURE SECTION
COLLEGE OF AGRICULTURE, KOLHAPUR
Mahatma Phule Krishi Vidyapeeth, Rahuri- 413 722
(M. S.), India
2021

Research Guide	**:**	**Dr. M. D. Mali**
Department	**:**	**Horticulture (Vegetable science)**

An experiment entitled “Performance of Chinese cabbage hybrids under various growing conditions” was conducted in five different growing conditions *viz.,* 3 different shade nets (35%, 50% and 75%) shade intensity, polyhouse and open condition. Two hybrid varieties *viz.,* Sun-60 & Tropical Highland were used for the experimental research in month of December, 2019. The experiment was laid out in split plot design with ten treatment combinations and four replications.

The results indicated that among the different growing conditions, polyhouse condition (G_4) recorded maximum number of leaves (20.92) and plant height (34.98 cm). While leaf length (34.04 cm) and leaf width (22.96 cm) was at par with G_2 (50% shade intensity), (31.92 cm and 21.39 cm) respectively. Whereas open condition recorded minimum number of leaves, leaf length, leaf width and plant height (15.06, 26.42 cm, 17.73 cm and 28.16 cm respectively). Similarly among two hybrid varieties V_2 (Tropical Highland) recorded maximum number of leaves, leaf length, leaf width and plant height (17.20, 30.75 cm, 17.29 cm and 31.53 cm respectively).

Minimum number of days required for head initiation (28.42 days) and for harvest (58.95 days) were recorded in polyhouse. While open condition required maximum days for head initiation and days for harvest (38.87 days and 79.47 days) respectively. While in polyhouse recorded minimum days for head formation (30.54 days) which was at par with G_1 (35% shade intensity) (33.4 days) and G_2 (50% shade intensity) (33.87 days). Similarly V_1 (Sun-60) recorded minimum days for head initiation, head formation and harvest (33.68 days, 34.02 days and 67.70 days) respectively.

Maximum head length (29.01 cm) was recorded in polyhouse condition which was at par with G_2 (50% shade intensity) (27.16 cm), while open condition recorded minimum head length (23.68 cm). Likewise maximum head width (12.11 cm) was recorded in polyhouse which was at par with G_2 (50% shade intensity) (11.40 cm) and G_1 (35% shade intensity) (11.35 cm). While minimum head width (10.42 cm) was recorded in open condition.

Polyhouse recorded maximum head weight (694.33 g), size of head (351.28 cm^2), Yield per plot (10.79 kg) and yield per hectare (501.05 q), while open condition recorded minimum head weight (456.31 g), size of head (247.87 cm^2), yield per plot (7.13 kg) and yield per hectare (330.20 q). Similarly among the hybrid varieties V_2 (Tropical Highland) recorded maximum head weight (564.72 g), size of head (305.55 cm^2), yield per plot (8.81 kg) and yield per hectare (408.63 q). While V_1 (Sun-60) recorded minimum head weight (530.76 g), size of head (282.82 cm^2), yield per plot (8.27 kg) and yield per hectare (382.98 q).

The lowest aphid incidence (4.81%) and caterpillar incidence (9.06%) was recorded in polyhouse while, the highest incidence was found in open condition (17.44% and 27.35%) respectively. Similarly among the hybrid varieties V_2 (Tropical Highland) recorded the lowest aphid and caterpillar incidence (11.28% and 19.13%) respectively. While V_1 (Sun-60) recorded maximum aphid and caterpillar incidence (11.99% & 20.16%) respectively.

Based on overall performance, it is concluded that Chinese cabbage hybrid variety Tropical Highland found suitable for improving growth and yield during rabi season under polyhouse condition than other growing conditions.

Shreerama T. Pages:- 1- 53

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1. INTRODUCTION

India has furnished with a diverse range of tropical, sub-tropical and temperate vegetables. Still there are some crops which are rare or unknown to majority of our growers and consumers. Our farmers can earn a lot by cultivating these rare high value cole crops near cities (peri-urban areas) as they fetch high prices in cosmopolitan markets, five star hotels and places of tourists' attractions. They can also be exported to other nations, particularly those in Europe, where their farming is not possible throughout the year under open field conditions. But due to lack of knowledge about their cultural practices, in our conditions the availability or cultivation of these vegetables is still limited (Pandey *et al*. 2020).

Chinese cabbage, Sprouting broccoli, Brussels sprouts, Red cabbage, etc. have given new opportunities for farmers of our country for diversification and off-season production owing to high demand in cities. But due to lack of preference in food among Indians some of the newly introduced vegetable crops failed to gain popularity though they are rich in protein, carbohydrates, vitamins, fibers and minerals (Lei *et al*. 2009). However, with the growing tourist industry and nutritional awareness among people, these vegetable crops are becoming popular. Among the cole crops, Chinese cabbage is more nutritious than other Cole crops such as cauliflower, cabbage, knolkhol, etc. It is fairly rich in ascorbic acid and carotene and it is also high in riboflavin, thiamin, iron and niacin. Realizing the extreme potential of Chinese cabbage in foreign and domestic market, the cauliflower cultivators of West Bengal's Terai zone are gradually adopting its cultivation (Yan *et al*. 2011).

To popularise these high value vegetables and its cultivars among the small and marginal farmers, proper demonstration should be followed through monitoring, personal interaction, motivation and awareness creation about benefits. Efforts are made on to encourage farmers and consumers of West Bengal (India) in adopting new exotic vegetables and varieties, which have had a significant impact on ground level and helped the state in addressing the problems of hunger, malnutrition and under nutrition not only in West Bengal but elsewhere in the country as well. But, no comprehensive analysis of these vegetable crops has been done in our region. However, state is aided with favourable and good agro-climatic condition for cultivation of these vegetables (Thapa and Rai 2012).

Chinese cabbage (*Brassica rapa* var. *pekinensis*) has a green colour head. The Napa cabbage also called Chinese cabbage. The term 'Chinese cabbage' is used to describe a wide range of Brassica crops, both loose leaf (with or without flowers) and those which form a dense head (Pandey *et al*. 2020).

Chinese cabbage is annual to biennial crop but normally it is grown as an annual crop which takes from 55 to 100 days from sowing to maturity, depending on variety. Loose headed forms are usually 2-3 weeks faster than the compact headed forms. Chinese cabbage is very

popular and frequently eaten vegetable in Southeast Asia. It is grown on commercial scale in China, Taiwan, Korea, Japan and Mongolia for its edible leaves. Every year around 40 million tonne is consumed in China and 1 million tonne in Japan. Due to its high tonnage and rich nutritive values, its cultivation is gaining momentum in other countries, including India. Two types of Chinese cabbage *viz.* head and leaf types are more common. These forms with loose heads were developed for the areas with hotter summer, while compact-headed forms were developed for the cooler areas (Rana 2008). The loose headed forms are less prone to bolt, more resistant to cold and more disease resistant. The head of Chinese cabbage is not round like a common cabbage head but cylindrical (Michilhili type) or barrel (Wong Bok) shaped with a broad central midrib. The cylindrical head of Chinese cabbage is firm but not as firm as cabbage at maturity. The outer foliage and wrapped leaves are characteristically pale green, whereas, the inner leaves are blanched to a creamy white in colour. The leafy type Chinese cabbage has thick white leaf stalk (petiole) and smooth, glossy, dark, green and almost round leaf blades. Flowering Chinese cabbage has small flowers born on top of erect flower stalks varying in colour from yellow to purple depending on variety. Whole plants are harvested in about 40-45 days when two or three flowers have opened (Rana, 2008).

Chinese cabbage is rich in carotene, vitamin B_1 and B_2 and contains more vitamin C than lettuce. Among organic acids, citric acid is major acid found in Chinese cabbage. The total glucosinolates content in Chinese cabbage varies from 0.097 - 0.337 g/kg fresh weight (average 0.198) in heading type and 0.390 - 0.704 g/kg (average 0.534) in leaf type (Lewis and Fenwick, 1988).

Cultivation of horticultural crops under controlled environments or greenhouse is one of the most promising measures for growing vegetables. Cole crops in general are sensitive to weather conditions. Greenhouse provides an excellent facility for protected and also for controlled environment, for cultivation of high value crops. Those people who are residing in metropolitan cities can use their roofs and open floor for greenhouse cultivation for domestic consumption. Temperature plays a major role with regards to growth and development of cole crops under different agro-climatic condition. The green house are usually covered structures of plastic film which allow the solar radiation to pass through it but traps the thermal radiation emitted by plant inside. The CO_2 released by the plants at night also trapped inside, which increases the rate of photosynthesis at day time. The evaporation from the plants and soil also raises the humidity inside (Sirohi and Behara, 2000).

Shade nets can be used to protect the sensitive plants from unfavourable environmental conditions. There are many advantages of protected cultivation over the open field cultivation such as environment control permits raising plants wherever in the world at any time of the year *i.e.* crops could be cultivated under the severe climatic conditions when it would not be

otherwise likely to cultivate the crops under the open field conditions. The crop yields are at the higher level per unit volume, per unit area and per unit input basis. Controlling the micro-climate permits the production of higher quality products which are pathogen free, insect free, and free from chemical residue. Prado *et al.* (2008) revealed that more than one layer of shade net used in growing broccoli results in bigger heads, taller plants, and less pest occurrence, thus helps in resulting higher yield and reducing death rate. Due to control of micro-climate, high quality and high value crops could be cultivated for export markets.

The environmental condition like temperature has great influence on yield and yield attributes of Chinese cabbage. In the same way, different cultivars have different growth, yield and quality parameters varying with growing conditions.

Keeping all these points in view, the present investigation, "Performance of Chinese cabbage hybrids under various growing conditions" was undertaken at the department of Horticulture, RCSM College of Agriculture, Kolhapur with following objectives

1. To evaluate the Chinese cabbage hybrids for growth characteristics under various growing conditions
2. To evaluate the Chinese cabbage hybrids for yield and yield attributing characteristics under various growing conditions
3. To study pest and disease incidence on Chinese cabbage hybrids under various growing conditions

2. REVIEW OF LITERATURE

2.1 Effect of growing conditions on growth characteristics

Yungwei (1995) conducted an experiment on the influence of microclimate in structures on cabbage plug sapling and revealed that germination percentage, leaf area and fresh weight of plant were greatest in the greenhouse followed by the plastic house. The survival rate & yield from transplants raised in the plastic and greenhouse were superior than those from net house.

Chen and Jiang (1998) observed the effect of shade (zero, thirty and sixty five *per cent*) on photosynthesis and growth of various varieties of capsicum. They revealed that the leaf area, plant height, carotenoid and chlorophyll content were increased with increase in specific leaf weight and leaf thickness with increased shade percentage.

Weng (1999) made study on *Brassica chinensis* in glass house and observed that the fresh weight, dry weight and growth rates were increased with increasing photosynthetically active radiation and temperature. The dry and fresh weight along with growth rates showed a quadratic relationship with air temperature in glasshouse and was positively affected by photosynthetically active radiation.

Srivastava *et al*. (2002) studied the performance of four growing conditions on the growth and yield of early cauliflower cv. Pant Gobhi-4 in rainy season. Results indicated that plant spread, plant height, number of leaves & yield were maximum in low cost polyhouse which were closely followed by low tunnel.

Suseela (2002) revealed that there was non-significant variation in plant spread, plant height and no. of leaves in cauliflower among the various greenhouses which vary in their ridge heights. The plant spread and plant height in the open field condition was significantly lesser than the entire greenhouse but not the number of leaves. The plant spread in the 3.0 m greenhouse was significantly lesser than that in 3.75 m greenhouse. But the 3.75 m and 4.5 m greenhouse were on par. The number of leaves in 3.0 m greenhouse was significantly lower than the 3.75 m greenhouse.

Rangaswami *et al*. (2005) made an effort to design & develop a naturally ventilated greenhouse suitable for tropical climate of Coimbatore district. The study evaluated the effect of greenhouse height (3.4 m, 7.5 m, and 4.5 m) and various levels of roof (zero, three & six%) and side (5, 10, 20, 25, 30, and 35%) ventilation on microclimate. The effect of microclimate on growth and yield parameters of cauliflower was studied. Under cropped condition temperature inside greenhouse declines & relative humidity increases with rise in height of greenhouse. Cauliflower yielded better when average maximum temperature during vegetative and curd initiation stages inside the greenhouse was less than 30.5°C whereas, when it surpassed 32.5°C, showed abnormal vegetative growth and low yield.

Francescangeli *et al*. (2006) carried out experiment in greenhouse under black shading meshes under control condition, in 35 and 70 *per cent* mesh for broccoli "Legacy" hybrid cultivar and found that shading did not affect the stem length and no. of leaves and accumulated intercepted PAR (Photosynthetically Acive Radiation) were negatively related. The dry weights of the leaves were at average of 45.7 *per cent* of total dry weight despite, greater leaf area developed under shade also found that photosynthetically active radiation affects curd initiation, leaf erectness, area, stem length and height.

Swagatika *et al.* (2006) sstudied that cauliflower sowed in September and grown under shade net produced the maximum number of leaves, plant height, girth and curd yield as compared to grown under open field environment.

Dixit (2007) studied the performance of spinach, amaranthus (*Amaranthus sp*.), fenugreek & coriander (*Coriandrum sativum*) under field and greenhouse conditions. Spinach, amaranthus, fenugreek and coriander recorded higher values of plant height, number of leaves/plant, number of branches, length of leaves, breadth of leaves & average yield when grown in the greenhouse than in the open field.

Khattak *et al*. (2007) observed the response of exotic tomato cultivars under zero, fifty five & seventy five *per cent* shading intensities. Shading intensity of 75% registered the highest no. of leaves, plant height, days to flowering and fruiting and yield per plot. While lowest number of leaves, plant height, days to flowering and fruiting, and yield per plot were registered in control.

Rahman *et al.* (2007) conducted an experiment to study the response of cauliflower cv. Nautilus F1 to different radiation integral safer curd initiation by covering the plants with different levels (0, 38, 50 and 68%) of neutral shading materials. Further, they reported that the cauliflower growth and development declined with increasing shade levels after curd initiation. Curd growth also increased linearly with increasing accumulated incident radiation integral with greater mean relative curd dry matter increase per MJ under lower incident radiation conditions than higher incident radiation levels.

Dhatt and Kaler (2009) observed the influence of shade net & growing media on nursery raising of cauliflower in subtropical zone. Among the 3 shade treatments, agro shade net (green colour six mesh size, twenty five *per cent* reduction of sunlight), monofilament insect net (white color twenty six mesh size, ten *per cent* reduction of sunlight) and open field. In terms of cauliflower number of true leaves, germination, plant height, seedling length, dry matter, days to harvesting, field establishment of transplant, and yield, the monofilament insect net produced the superior results.

Lei *et al.* (2009) revealed that the non-heading Chinese cabbage plants developed healthier under the stronger radiance (100% & 60%) with a substrate water holding capacity of 80 *per cent* or 60 *per cent* substrate moisture under lesser light intensity (thirty *per cent*).

Panigrahi *et al*. (2010) conducted comparative study on capsicum cv. California Wonder under open field and protected condition & stated that yield and yield attributing characters *viz.*, number of primary branches, plant height, number of leaves, length of fruit, no. of fruits plant^{-1}, girth of fruit and yield were better under protected environment as compared to open field condition.

Srivastava *et al*. (2011) observed the performance of early cauliflower under naturally ventilated polyhouse and revealed that, the cultivar Pant Composite had the tallest plant, while the cultivar Pusa Meghana had the shortest plant and the broadest leaf lamina. Highest number of leaves per plant and the lengthiest leaf were recorded by the cultivar Pant Gobhi-3. Early Himlata had the most curd weight, followed by Pusa Deepali and Pusa Meghana. The former also yielded maximum followed by Early Kunwari. The earliest maturity was recorded in Pusa Meghna followed by Early Kunwari. The cultivars Early Kunwari, Early Himlata, and Pusa Meghana were shown to be the best suitable for protected monsoon season cultivation in a naturally ventilated polyhouse, based on all characters such as curd size, vegetative development, yield and crop period.

Yan *et al*. (2011) studied effects of shading on growth & quality of flowering Chinese cabbage under different color shading-nets. Under grey, blue, red and black net at 12 a.m., temperature decreased by 5.81, 1.27, 3.93 and 8.58°C, and the relative humidity increased by 18.75, 18.32, 26.69 and 2.48%, respectively. Plant fresh weight was increased by 41.71 and 5.36% under red and blue net, while same was decreased by 14.66 and 49.55% under grey and black net, respectively. Shoot fresh weight was increased by 43.80 and 9.00% under red and blue net, while it was decreased by 12.81 and 48.62% under grey and black net, respectively. Plant height was increased by 16.25% under red net, however it was decreased by 33.01%, 12.73% and 47.50% under grey, blue & black net. Leaf area was increased by 41.44, 23.05 and 15.70% under red, grey and blue net, respectively.

Kotadia *et al*. (2012) stated that leafy vegetable crops cultivated in shade net condition was ideal for plant growth attributes and yielded more as compared to open field condition during summer period. Growing spinach and amaranthus under a 30% shade net resulted in rapid development in terms of leaf number, length of root, plant height and leaf area.

Chattarjee and Mahanta (2013) carried out an experiment on off season cauliflower during summer in shadenet to identify optimum planting time and proper nutrient source for summer season cauliflower. Four dissimilar planting dates and four nutrients were utilized and found that planting date 14th May registered tallest plant, highest number of leaves, maximum

curd weight, curd yield and nutrient sources have significant effect on off season cauliflower production.

Juan and Diaz (2013) reported that with increased shade level, the total plant leaf area, individual leaf area and individual leaf weight were increased, whereas leaf number per plant and specific leaf weight were decreased and morphological changes such as taller plants and thinner and larger leaves, likely enhanced light capture under shaded conditions compared with unshaded plants.

Rajasekar *et al*. (2013) observed that mean weekly temperature during summer & winter was greater under open field conditions in comparison with shade net house. Due to the lower temperature the number of branches, plant height, internodal length, average fruit weight, and yield per plant are all higher in the shade net house than in the open field condition. Hence, regardless of the season, growing tomato, chilli, brinjal, radish, cucumber, amaranthus, chinese cabbage and coriander under shade net conditions will be more profitable.

Ramanarao *et al*. (2013) evaluated the performance of capsicum crop in open field and under covered cultivation and stated that the plant height, number of branches plant^{-1}, number of leaves plant^{-1} as well as root zone length were maximum for the capsicum crop grown in shade net over open field.

Malshe *et al.* (2016) evaluated different capsicum cultivars under open & protected conditions and revealed that, the treatment comprising of Manhattan variety recorded maximum plant height under protected conditions while California Wonder recorded maximum plant height under open condition.

Ngullie and Biswas (2016) conducted experiment on performance of capsicum under protected & open field conditions. The result found that capsicum grown under polyhouse displayed significant rise in plant height and number of structural branches. The fruit weight, yield, number of branches were also significantly higher under polyhouse.

Santosh *et al.* (2016) reported that greenhouse, shadenet and different types of protected structures were appropriate for winter vegetable crops (tomato, cabbage, cauliflower and broccoli) as greenhouse structure offers a solar energy saver and enhances temperature inside the structures and found that vegetable production in winter for sub humid region was reduced due to low temperature below optimum level.

Andhale *et al.* (2017) selected three shadenet colors *viz.*, blue, white, and green + white with three different shading intensities *viz*., thirty five, fifty and sevety five *per cent* for cabbage cv. Scent and Saurabh. The results revealed that APAR (Absorption of Photosynthetically Active Radiation) and photosynthetic rate were significantly enhanced under white colored shadenet followed by blue and green + white shadenet colors in thirty five *per cent* shading intensity than fifty and seventy five *per cent* shading intensities. Scent variety registered higher APAR

(Absorption of Photosynthetically Active Radiation) and photosynthetic rate than Saurabh variety.

Pooja and Hakkim (2017) conducted comparative study on tomato under polyhouse and rain shelter conditions and reported that during all growth stages, the plant height and internodal length were significantly more inside the polyhouse than rain shelter while the higher stem girth and numbers of leaves plant^{-1} were observed under rain shelter structure than polyhouse.

Yadav *et al*. (2017) assessed the effect of 4 levels of spacing and three levels of training in polyhouse grown tomato. Among the training systems, the single stem training system registered the tallest plant and leaf area with least days for first harvest whereas, the three stem training system recorded the significantly superior stem diameter, number of branches per plant over single and two stem training systems irrespective of plant spacing.

Garde (2018) carried out an experimental trial on Effect of different growing conditions on growth, yield and quality of leafy vegetables with 2 growing condition, open field and polyhouse condition and four leafy vegetable *viz.,* amaranthus, beet leaf, coriander and fenugreek comprising eight treatments replicated thrice. Results indicated that the high values of growth attributes *viz.,* plant height, number of leaves plant^{-1}, leaf length, leaf width, length of root and lesser days required for horticultural maturity and yield attributes *viz.,* yield plot^{-1} and yield per ha were registered in polyhouse condition than open conditions.

Yasoda *et al.* (2018) studied the effects of twenty five, fifty and seventy five *per cent* shade net intensities on growth & yield performance of cauliflower and observed that the cauliflower grown in different shade levels showed great influence on plant growth, yield attributes and quality and found that maximum number of leaves, curd weight, curd width in 50 *per cent* shade net. Maximum plant height was recorded in seventy five *per cent* shadenet.

Singh *et al.* (2019) conducted an experimental trial on Varietal performance of brinjal under different growing conditions in which brinjal varieties *viz*., White long, White round, Chu-Chu, Shyamal, Purple round, Him mani- 412, Sharapova and Nisha were grown under 2 different growing conditions *viz.*, poly-tunnel and open field. Growing conditions and varieties had influenced significantly on the growth, yield and yield parameters. The poly- tunnel grown eggplant observed maximum number of leaves and plant height at thirty, forty five and sixty DAT and number of branches at 45 and 60 DAT and most of the yield and yield parameters than the open field. It was observed that, plant height (30, 45 and 60 DAT) was maximum in Sharapova variety, followed by Shyamal, while the maximum no. of leaves (Thirty, forty five & sixty DAT) and number of branches (45 and 60 DAT) were observed in Shyamal variety, followed by Purple round. The variety Shyamal performed best with respect to yield and most of the yield parameters followed by Sharapova. While, the no. of fruits / plant was maximum in White long followed by Shyamal.

Rane (2020) studied on the performance of knol-khol under greenhouse & open field conditions with 6 promising varieties of knol-khol *viz.,* KSP-5311, Giant, Early White Vienna, Videsi EWV, Neo and local planted under open and greenhouse conditions. The results found that most of the attributes studied has better values in greenhouse than open field condition due to favorable growing climate *viz.*, number of leaves/plant, length of leaves, leaf width, days required for knob formation, weight of knob, size of knob and yield/ha as compared to open field condition & also showed that variety Giant had higher values than all other varieties in greenhouse.

Ashok and Ravivarman (2021) studied the influence of season and cultivating environment on the growth & yield of coriander var. CO (CR) 4. Among the growing conditions, coriander cultivated under polyhouse recorded maximum germination percentage, plant height, number of branches, number of leaves/plant and yield per hectare followed by shadenet house and open field condition.

2.2 Effect of growing conditions on yield and yield attributing characteristics:-

Protected cultivation of cauliflower by Nagalakshmi *et al.* (2001) revealed that cauliflower grown in the polyhouse showed shorter duration of curd development than those in open field.

Agarwal *et al*. (2003) studied cultivation of cole crops under protected environment and in open field. They concluded that the cauliflower, Knolkhol and cabbage yielded higher (5.47 kg/m^2, 3.61 kg/m^2 and 8.55 kg/m^2 respectively) inside the greenhouse and the same was minimum in outside of greenhouse (4.42 kg/m^2, 2.22 kg/m^2 and 6.70 kg/m^2 respectively). Circumference of curd of cauliflower, knolkhol and cabbage was found higher (49.65 cm, 27.28 cm and 48.63 cm respectively) inside the greenhouse & the same was found lower (44.60 cm, 23.95 cm and 42.35 cm respectively) in open field. Average curd weight also found better (985.75 g, 291.26 g, and 154.25 g cauliflower, Knolkhol and cabbage respectively) as compared to outdoor cultivation (796.35 g, 220.62 g and 1206.98 g cauliflower, knolkhol and cabbage respectively).

Minz (2004) studied on Effect of growing conditions, spacing and nutrition on growth, yield and quality of sprouting broccoli (*Brassica oleracea* var. *italica*). Results revealed that the plant grown under polyhouse condition was significantly better with respect to growth parameters such as number of leaves (18.32), leaf area (205.78 dm^2), early head initiation (44.26 days) and earlier harvest as compared to open condition at harvest. Significantly maximum yield /plot (4.88 kg), yield / hectare (12.05 t/ha) & other characters such as head size (138.70 cm^2), head weight (311.15 g) were recorded under polyhouse condition than open field condition.

Kamaruddin (2007) reported that high value tropical and temperate crops such as tomato, capsicum, cabbage muskmelon, cucumber were successfully grown under naturally ventilated

structure using hydroponics system in the low lands. The yield of the crops was found 2-4 times higher when compared to open field conditions. Year round production of premium quality vegetables is also possible. In addition it reduced labour requirement and saved operational time.

Vethamoni and Natarajan (2008) observed the influence of 3 different shade levels (35%, 50% and open field condition) on growth and yield of sweet pepper varieties Indra and Kohinoor during two seasons viz., September, 2004 to March 2005 (Season-I) and June to December, 2005 (Season-II) and 35% shading intensity was observed suitable for year round farming of sweet pepper under tropical zones.

Milenkovic *et al.* (2010) conducted experiment and revealed that red & pearl shade nets significantly increased the total yield of tomato which was allied with both high productivity (number of fruits produced per plant) & larger fruits. Tomato under fifty % shade had similar fruit yield in comparison with yield achieved from forty *per cent* color shade nets, except in black shade nets where yield were lowest than control. Plants cultivated under black colour nets with fifty % shadow had smaller yield for 8.7 *per cent* than plants grown without nets-control. On an average of two years, the total fruit yields under the colored shade nets were greater by 11.9 - 22.8 *per cent*, relative to the equivalent black shade net.

Kanwar (2011) conducted experiment on tomato under greenhouse and open field conditions in the trans-Himalayan region of India. The study found that the performance of all tested tomato genotypes is far superior in the polyhouse, as compared to open field conditions, for all considered characters. The polyhouse produced 136.22% more yield per ha and 188.35% more fruits per plant as compared to open field.

Karistsapol *et al.* (2013) evaluated the effects of shadings and cultivars Top green, Green queen and Yok kheo of broccoli (*Brassica oleracea* L. var. *italica* plank) on growth and yield and observed that broccoli can be adapted to shading by increasing seedling survival rate, plant height and plant breadth. The Yok Kheo cultivar recorded highest head diameter (12.11 cm), head weight (371.48 g/plant) and yield (10.92 t/ha)under the shade which was significantly superior over open field conditions.

Surve and Mudgul (2013) reported the response of cabbage varieties in different shadenet colors and in open field on growth, maturity period and yield. The red shadenet color with seventy five % shading intensity recorded significantly increase in cabbage yield (28.73 t ha^{-1}) with higher head weight (674.83 g) followed by green, green + white and white shadenet colors. Open field conditions recorded lowest head weight (397.03 g) with yield (8.21 tha^{-1}).

Thapa *et al*. (2013) carried a study on Production of quality sprouting broccoli (*Brassica oleracea*var. *italica*) under cover and open condition & stated that plants grown under polyhouse recorded the maximum production in all the 4 cultivars as compared to the plants cultivated under open field condition. Curd yield of Early you was maximum under polyhouse condition

and also reported that curd initiation and curd formation was recorded earlier under polyhouse condition than in open condition.

Andhale *et al.* (2014) conducted experiment on capsicum under three different shading intensities viz., 35, 50, and 75 *per cent*. The micrometeorological studies indicated that (APAR) Absorbed Photosynthetically Active Radiation & light use efficiency were slightly increased in 35% shading intensity, hence the higher photosynthetic rate & eventually yield of capsicum (118.59 t ha^{-1}) followed by fifty % shading intensity (97.81 t ha^{-1}) and 75 *per cent* (81.50 t ha^{-1}) were observed respectively.

Saleem *et al*. (2014) studied cultivation of cabbage hybrid S-92 'Mitra' under low tunnel & open field conditions in cold arid ladakh region & concluded that the total cabbage yield was significantly higher under low tunnels (290.2 q/ha) as compared to open field conditions (186.3 q/ha).

Nangare *et al*. (2015) studied the effect of three green shade nets (35, 50 and 75%) on yield and quality of tomatoes and reported that there was no significant difference found in average monthly temperature and humidity inside shade net house and open field (control). Significant difference was recorded in yield. Highest average plant yield of (3.49 kg/plant) was found in 35 % shading net followed by open field (2.27 kg/plant) with lowest yield observed (1.07 kg/plant) in 75 % shading net.

Kumar *et al.* (2016) conducted a study on two brinjal varieties *viz.* Pusa Purple Cluster and Pusa Purple Long to estimate their performance & suitability under open and naturally ventilated polyhouse conditions. Growing conditions had significant effect on parameters like days to marketable maturity, harvest period, plant height, no. of fruits $plant^{-1}$, fruit yield $plant^{-1}$ and fruit yield per ha. Number of fruits per plant and fruit yield per ha were 16.02% and 31.87% respectively higher under protected condition in comparison to open field. Pusa Purple Long was significantly early to reach marketable maturity and also registered the highest value for harvest period.

Laczi *et al*. (2016) conducted experiment on Organic farming of Chinese cabbage (*Brassica rapa* var. *pekinensis*) under polyhouse and open condition and revealed that the best yields were observed when horse manure was used (between 76.60 & 99.20 t/ha), followed by cattle manure (b/w 76.90 and 93.85 t/ha). A higher yield of better quality cabbage was obtained in a polyethylene tunnel (89.28 t/ha) as compared to the open field culture (77.40 t/ha). Hybrid Super gave the highest yield (92.70 t/ha), followed by hybrid Vitimo (86.09 t/ha). They also reported that Chinese cabbage head length, head width, head size and head weight was found more in protected areas when compared to open condition. The experimental results showed that this kind of cabbage can be grown with maximum success in protected areas such as greenhouses or polyethylene tunnels.

Meena *et al*. (2016) carried out research trial for evaluating the effect of shadenet colors, its intensity & fertilizer levels on growth parameters of beetroot which indicated that red shadenet color significantly increased beetroot yield. The yield gained from red colored shadenet was (28.03 t ha^{-1}) and that of green and black colored shadenet was (25.23 and 21.87 t ha^{-1}) respectively. Leaf area of plant at thirty, forty five, sixty DAS and at harvest (9.88, 18.64, 29.63 and 38.56 dm^2 respectively). The thirty five *per cent* shading intensity increased beetroot yield significantly as (29.32 t ha^{-1}) as compared to 50 *per cent* and 75 *per cent* which was (26.22 t ha^{-1} and 19.57 t ha^{-1}) respectively. Also plant spread at thirty, forty five and sixty DAS and at harvest were 28.40, 40.13, 51.99 and 57.46 cm respectively in thirty five % shading intensity.

Pathan and Mathad (2017) conducted an experiment to assess the effect of 3 levels of spacing and four levels of training on yield of cherry tomato under 35% shade house and achieved significantly highest yield per cluster (145.20 g) in single stem training system however, the maximum fruit yield $plant^{-1}$ (3.78 kg) and per m^2 (7.49 kg) were recorded in four stem training system.

Babu and Reddy (2017) studied the performance of sprouting broccoli cv. Green Magic under polyhouse, fifty % shade net and open field conditions during winter season. Among the three different growing conditions naturally ventilated polyhouse (NVPH) recorded highest head width (9.28 cm), head weight (265.0 g), Yield per plot (9.54 kg) and marketable yield (7.95 t ha^{-1}) which was at par with open field conditions i.e. head diameter (9.22 cm), head weight (234.34 g) and marketable yield (7.03 t ha^{-1}). Number of days for head initiation was lowest in open field conditions (61.14 days) which was at par with Naturally ventilated polyhouse (62.14 days) & number of days for head development was lowest in open field conditions (26.71 days) followed by NVPH (29.86), which was at par with 50% shade net (30.14 days).

Ansary *et al.* (2019) conducted a study on late planted capsicum under two production system *i.e* polyhouse & open condition with 3 dissimilar hormonal treatments *viz.* application of triacontanol @ 0.5 ml per litre at full bloom phase, application of planofix (4.5 *per cent* NAA) @ 0.25 ml per litre at full bloom phase, application of Ethrel @ 0.3 ml per litre at full bloom phase along with a control. Growth & yield of capsicum were significantly effected by dissimilar hormones under both conditions. Among the hormones, planofix had finest effect to result highest fruit weight (123.2 g & 97.4 g), no. of marketable fruits / plant (5.5 & 4.3) and yield (39.5 t/ha and 28.3 t/ha) in polyhouse & open field condition respectively. Whereas in both polyhouse and open field conditions, ethrel treatment resulted in the maximum number of total fruits (8.3 and 7.3, respectively). Finally they concluded that polyhouse was more successful to increase the yield of high quality fruits in capsicum than open field condition.

Pandey *et al.* (2020) evaluated Four vegetables, *viz*, Broccoli, Red Cabbage, Cauliflower and Chinese Cabbage under protected cultivation structures (glass house, poly house,

polycarbonate house, open field covered with colored plastic mulches) and open field. In view of the experimental results obtained during the investigation, maximum yield was observed under protected cultivation structures than in open field for Chinese cabbage, Broccoli, Red Cabbage, and Cauliflower.

2.3 Effect of growing conditions on Pest and Disease incidences

Costello and Altieri (1991) conducted experiment for maintaining the population of cabbage aphid. *Brevicoryne brassicae*, green peach aphid and *Myzus persicae* on broccoli which was interplanted with white, red and strawberry cover and found that living mulches had lower aphid populations. Although differences with clean cultivation were greatest in early season for *Myzuspersicae* which was diminished over time. No effect of cropping system was seen on growth rate of *Brevicoryne brassicae*, but *Myzus persicae* growth rates were higher in living mulches compared to clean cultivation.

Bextine *et al*. (2001) studied that the transmission of yellow vine disease (a phloem limited bacteria) in squash plants was prevented by row covers. The vectors of this disease are spotted cucumber beetles (*Diabroticaundecim punctata* Howardi), squash bugs (*Anasa tristis*) and striped cucumber beetles (*Acalymma vitatum*). The disease incidence was not found in squash with row covers because it blocked the entry of dangerous insect pests that acts as vector for the disease to plants.

Singh *et al.* (2004) observed incidence of mites, fruit borer, aphids and white fly on hybrid sweet pepper under protected condition in India. On sweet pepper, the pepper yellow vein mosaic virus (PYVMV) vectored by aphids was found. It was not recorded in September- March crop under protected condition whereas, 40% incidence was observed in open field condition. In June- December, incidence was less in greenhouse as compared to open. Total yield loss in greenhouse was 38.24% to 41.64% and in open field, 53.18% to 62.27% depending on phase of the crop and time of infestation.

Elad *et al*. (2007) stated that green nets were allied with lesser disease levels in the experimental trial of pepper crop.

Prado *et al.* (2008) studied that broccoli raised in 2 and 3 layered shade nets were less susceptible to insect pests and thus had lower death rate than those grown in open fields.

3. MATERIAL AND METHODS

An experiment entitled “Performance of Chinese cabbage hybrids under different growing conditions” was conducted at the Instructional-cum-Research Farm of Horticulture Section, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur in winter, 2019. The details of the materials used and the methods employed during the course of investigation are presented in this chapter.

3.1 Experimental site

The experimental trial was conducted during the winter, 2019 at the Instructional-cum-Research Farm of Horticulture Section, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur located at 16° 41’ North latitude and 74°16’ East longitude. The elevation of Kolhapur is 548 meter above mean sea level. Agro-ecologically this area comes under *sub-montane* zone of Maharashtra state with annual rainfall range of 1000 to 2500 mm with an average of 1057 mm out of which, 80% rainfall is received from SW monsoon from June to September while rest of rainfall from North East monsoon.

3.2 Climate

The data regarding weather parameters recorded in the meteorological observatory at RCSM College of Agriculture, Kolhapur during experimentation (Appendix I).

3.3 Methodology

3.3.1 Shade net house

The 3 shade net houses of 12.0 m x 9.0 m in length and width, with shading strengths of thirty five, fifty, and seventy five *per cent*, respectively were used. On each bed, two lateral drip lines were installed down the crop row, with drippers spaced 30 cm apart for each plant. The shade net was also provided with the foggers to protect the crop from extreme heat and to regulate the humidity. Besides this, foggers also helps in creating microclimate.

3.3.2 Polyhouse structure

The crop was grown inside a naturally ventilated polyhouse of size 27.40 m x 18.60 m (L x B) during the winter, 2019.

3.3.3 Open field

Plain land adjacent to green house was used for the evaluation of open field condition.

3.4 Details of experiment

3.4.1 Experimental Details

1. Crop : Chinese cabbage
2. Design : Split plot design
3. No. of Treatments : 10
    a) Main Treatments : 05

b) Sub treatments : 02

4. No. of Replications : 04
5. Season : Winter, 2019
6. Spacing : 45 cm X 30 cm
7. Plot size : 2.4 m x 1.0 m
8. Planting layout : Raised beds
9. Location : Instructional-cum- Research farm, Horticulture Section, RCSM College of Agriculture, Kolhapur

3.4.2 Treatment Details

a. Growing conditions

G_1: Growing condition with 35% Shade intensity

G_2: Growing condition with 50% Shade intensity

G_3: Growing condition with 75% Shade intensity

G_4: Polyhouse condition

G_5: Open condition

b. Varieties

V_1:- Sun 60

V_2:- Tropical Highland

c. Table 3.1. Treatment combinations

Treatments	Treatment combination	Interaction details
T_1	G_1V_1	Sun-60 in 35% Shade intensity
T_2	G_1V_2	Tropical Highland in 35% Shade intensity
T_3	G_2V_1	Sun-60 in 50% Shade intensity
T_4	G_2V_2	Tropical Highland in 50% Shade intensity
T_5	G_3V_1	Sun-60 in 75% Shade intensity
T_6	G_3V_2	Tropical Highland in 75% Shade intensity
T_7	G_4V_1	Sun-60 in Polyhouse condition
T_8	G_4V_2	Tropical Highland in Polyhouse condition
T_9	G_5V_1	Sun-60 in Open condition
T_{10}	G_5V_2	Tropical Highland in Open condition

3.5 Cultural operations

3.5.1 Preparation of land in different growing conditions and fumigation

Soil was brought to a fine tilth by removing all weeds and stubbles. Two days later, farm yard manure (FYM) and fine sand were mixed uniformly and incorporated into the soil in a ratio of 40% red soil + 20% sand + 40% FYM. This homogenous mixture of media was disinfected

with 0.4% Formalin (4 ml per litre) treatment to control the soil borne diseases. The media was then perfectly leveled and the raised beds of 2.4 X 1.0 X 0.45 m^3 were prepared.

3.5.2 Sowing and preparation of seedlings

The required quantity of seeds of two varieties of Chinese cabbage *viz.*, Sun-60 and Tropical Highland was procured from the Chandrashesh Traders Nursery, Pune (MS). Sowing was done on 10 December, 2019 on raised beds.

3.5.3 Transplanting

The beds were soaked with water and the healthy seedlings were transplanted on 11 January, 2020 at the spacing of 45 cm x 30 cm on the raised beds under all 5 growing conditions. A notch was taken to place the seedling with notch and surrounding soil being pruned to anchor the seedling.

3.5.4 Fertilizer dose

The recommended dose of fertilizer (RDF) @ 120:80:80 N: P_2O_5: K_2O kg ha^{-1} was applied during growing season through drip. Urea, Phosphoric acid and white potash were used as source of N, P_2O_5 and K_2O, respectively.

3.5.5 Gap filling

Optimum plant population was maintained by gap filling which was carried out 6 DAT.

3.5.6 Irrigation

Crops were irrigated on every alternative day through drip irrigation placed out on the bed.

3.5.7 Weeding

Four hand weedings were done during the experimental trial.

3.5.8 Management of growing conditions

The dried leaves were frequently removed. Sanitation was maintained inside the shade net and the structure was maintained clean by removing plant remains and weeds. Visitors were not allowed inside the protected structure because it could allow insect pests and vectors to enter into the protected structures.

3.5.9 Harvesting

Chinese cabbage heads were harvested separately when they were compact, firm and reached horticultural maturity.

3.6 Observations recorded

Six plants were selected randomly and tagged from each treatment from 4 replications to record the periodical observations at fifteen days interval during experimental trial.

3.6.1 Growth parameters

3.6.1.1 Number of leaves plant^{-1}

The total numbers of leaves of randomly selected six plants were calculated and average number of leaves per plant was recorded at an interval of 15 days.

3.6.1.2 Length of leaves (cm)

It was recorded at 15, 30, 45 DAT and at harvest. It was recorded from the distance between tip of leaves to pedicel using meter scale. The mean length of leaves was calculated and expressed in centimeter.

3.6.1.3 Width of leaves (cm)

It was recorded at 15, 30, 45 DAT and at harvest. It was recorded from the left edge of leaves to right edge using meter scale. The mean width of leaves was calculated and expressed in centimeter.

3.6.1.4 Plant height (cm)

Plant height was recorded at 15, 30, 45 DAT and at harvest. The mean plant height was calculated and expressed in centimeter.

3.6.1.5 Leaf colour and shape

Leaf colour and shape were noted during matured stage.

3.6.2 Yield observations

3.6.2.1 Number of days required for head initiation

Number of days required for head initiation from transplanting were recorded and the mean was worked out.

3.6.2.2 Days required for head formation

It is calculated by finding out the days between head initiation and days required for harvest.

3.6.2.3 Days required for harvesting

Number of days required for harvesting from transplanting was counted and the average was worked out.

3.6.2.4 Length of head (cm)

The length of head of Chinese cabbage was recorded by measuring each of the head with measuring tape from top of head to bottom of head vertically and expressed in centimeter and mean length of head plant^{-1} (cm) was worked out.

3.6.2.5 Width of head (cm)

The width of head of Chinese cabbage was recorded by measuring each of the head with measuring tape from left edge of head to right edge of head horizontally and expressed in cm and

mean width of head plant^{-1} (cm) was worked out.

3.6.2.6 Weight of head (g)

Weight of head was recorded on the same head which were used for recording the head width by measuring the weight of each head on weighing balance and expressed in grams.

3.6.2.7 Size of head (cm^2)

Size of head was calculated by finding out product of length and width of head and expressed in cm^2.

3.6.2.8 Yield plot^{-1}(kg)

The fresh head from net plot area at harvesting was calculated. The sum of head yield of net plot was calculated after harvesting of Chinese cabbage.

3.6.2.9 Yield hectare^{-1} (q)

The sum of head yield per hectare was calculated after harvesting of Chinese cabbage. This yield per hectare was then presented as quintal^{-1}.

3.6.2.10 Shape and colour of head

Shape and colour of head was noted after harvesting.

3.6.3 Pest and disease incidence (%)

The pest and disease occurrence were counted on per plant basis and expressed in *per centage*.

3.7 Statistical analysis

The data recorded were analyzed statistically using technique of analysis of variance and significance was determined by Split plot design (Panse and Sukhatme, 1985). The standard error of mean (S.Em.±) was calculated. Whenever, the results were significant, the critical difference (CD) at 5% level of significance was worked out and presented. The suitable graphical diagrams of the data have been given at suitable places.

4. RESULTS AND DISCUSSION

An experiment entitled “Performance of Chinese cabbage hydrids under various growing conditions” was carried out during winter 2019 to study the performance of Chinese cabbage hybrids in terms of growth parameters, yield and yield attributing parameters under Polyhouse, 3 different Shadenets (*viz.* 35%, 50% and 75% Shade intensity) and Open field condition. The data was subjected to statistical analysis and the systematic results are presented in this chapter with suitable sub headings and detailed discussion.

4.1 Growth parameters

4.1.1 Number of leaves/Plant

4.1.2 Length of leaves (cm)

4.1.3 Width of leaves (cm)

4.1.4 Plant height (cm)

4.1.5 Leaf colour

4.1.6 Leaf shape

4.2 Yield and Yield attributing parameters

4.2.1 Days required for head initiation

4.2.2 Days required for head formation

4.2.3 Days required for harvest

4.2.4 Length of head (cm)

4.2.5 Width of head (cm)

4.2.6 Average weight of head (g)

4.2.7 Size of head (cm^2)

4.2.8 Yield per plot (kg)

4.2.9 Yield per ha (q)

4.2.10 Colour of head

4.2.11 Shape of head

4.3 Pest and disease incidence

The incidence of major pest and diseases was recorded in the experimental plot.

4.1 Growth parameters

Various growth parameters *viz.*, number of leaves, length of leaves, width of leaves plant height, were recorded at 15 days interval till harvesting.

4.1.1 Number of leaves/Plant

The data on number of leaves per plant of Chinese cabbage as influenced by different treatment is presented in Table 4.1, 4.2, 4.3 and 4.4 and graphically depicted in Fig.2.

4.1.1.1 Effect of Growing conditions

The number of leaves per plant of Chinese cabbage was significantly influenced due to different growing conditions during all the crop growth stages. Maximum number of leaves were recorded at 15, 30, 45 DAT and at harvest in growing condition G_4 (Polyhouse condition) and were 9.75, 15.19, 18.83, and 20.92, respectively which was statistically at par at 15 and 30 DAT with G_2 (50% shade intensity) (9.50 and 14.20) and at par at 15 DAT with G_1 (35% Shade intensity) (9.21) followed by G_3 (75% Shade intensity) and G_5 (Open condition) growing conditions. The more number of leaves plant^{-1} in polyhouse might be due to optimum and congenial micro-climate that prevailed inside the green house. The results of the present investigation are in conformity with the results of Dixit (2007), Panigrahi (2010) in capsicum, Rane (2020) in knol-khol and Ashok and Ravivarman (2021) in coriander who also reported higher number of leaves under protected conditions as compare to open field condition.

Table 4.1 Number of leaves per plant as influenced by different growing conditions and hybrid varieties at 15 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	8.96	9.46	9.21
G_2 (50% Shade intensity)	9.25	9.75	9.50
G_3 (75% Shade intensity)	8.33	8.79	8.56
G_4 (Polyhouse condition)	10.04	9.46	9.75
G_5 (Open condition)	8.33	9.46	8.89
Mean	8.98	9.38	
	Growing condition	Hybrid variety	Interaction
S.Em.±	0.24	0.12	0.26
CD @ 5%	0.74	0.35	NS

Table 4.2 Number of leaves per plant as influenced by different growing conditions and hybrid varieties at 30 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	12.83	14.71	13.77
G_2 (50% Shade intensity)	14.08	14.32	14.20
G_3 (75% Shade intensity)	12.29	12.80	12.54
G_4 (Polyhouse condition)	14.66	15.73	15.19
G_5 (Open condition)	13.00	13.67	13.33
Mean	13.37	14.24	
	Growing condition	Hybrid variety	Interaction
S.Em.±	0.33	0.26	0.58
CD @ 5%	1.00	0.78	NS

Table 4.3 Number of leaves per plant as influenced by different growing conditions and hybrid varieties at 45 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	14.37	15.37	14.87
G_2 (50% Shade intensity)	14.33	15.71	15.02
G_3 (75% Shade intensity)	14.08	14.96	14.52
G_4 (Polyhouse condition)	18.58	19.08	18.83
G_5 (Open condition)	14.52	14.46	14.49
Mean	15.18	15.91	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.34	0.23	0.53
CD @ 5%	1.05	0.71	NS

Table 4.4 Number of leaves per plant as influenced by different growing conditions and hybrid varieties at harvest

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	15.50	16.29	15.90
G_2 (50% Shade intensity)	15.54	16.96	16.25
G_3 (75% Shade intensity)	14.91	15.91	15.41
G_4 (Polyhouse condition)	20.71	21.13	20.92
G_5 (Open condition)	14.42	15.71	15.06
Mean	16.21	17.20	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.44	0.31	0.69
CD @ 5%	1.37	0.93	NS

4.1.1.2 Effect of hybrid varieties

Among the two hybrid varieties significantly more number of leaves were found in V_2 (Tropical Highland) at all the growth stages *i.e.* 15, 30, 45 DAT and at harvest and were 9.38, 14.24, 15.91, and 17.20, respectively followed by V_1 (Sun-60) which were (8.98, 13.37, 15.18, and 16.21, respectively.

4.1.1.3 Interaction effect

The interaction effect between growing condition and hybrid varieties on number of leaves plant^{-1} of Chinese cabbage was found non-significant at 15, 30, 45 DAT and at harvest.

4.1.2 Length of leaves (cm)

The data on length of leaves plant^{-1} of Chinese cabbage as influenced by different treatments have been presented in Table 4.5, 4.6, 4.7 and 4.8 for 15, 30, 45 DAT and at harvest and graphically depicted in Fig.3.

4.1.2.1 Effect of growing conditions

The length of leaves plant^{-1} of Chinese cabbage was significantly influenced due to different growing conditions during all the crop growth stages. Significantly the longest leaves (22.22 cm, 29.08 cm, 31.90 cm and 34.04 cm) were observed in growing condition G_4 (Polyhouse condition) at 15, 30, 45 DAT and at harvest, respectively which was followed by at 15, 30, 45 DAT and statistically at par at harvest with growing condition G_2 (50% Shade intensity) (18.24 cm, 25.90 cm, 28.71 cm and 31.92 cm, respectively) followed by growing condition G_1 (35% Shade intensity), G_3 (75% Shade intensity) and G_5 (Open condition). Optimum climatic condition under polyhouse situation might have enhanced faster cell division and cell elongation, which eventually led to more vegetative growth. These results are in accordance with that of reported by Dixit (2007), Rane (2020) in knol-khol and Garde (2018) in leafy vegetables.

Table 4.5 Length of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 15 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	V_2 (Tropical Highland)	
G_1 (35% Shade intensity)	15.00	16.31	15.66
G_2 (50% Shade intensity)	17.03	19.46	18.24
G_3 (75% Shade intensity)	13.85	17.28	15.56
G_4 (Polyhouse condition)	22.61	21.84	22.22
G_5 (Open condition)	12.79	12.94	12.87
Mean	16.26	17.56	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.48	0.25	0.56
CD @ 5%	1.48	0.75	1.68

Table 4.6 Length of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 30 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	V_2 (Tropical Highland)	
G_1 (35% Shade intensity)	22.54	24.66	23.60
G_2 (50% Shade intensity)	25.11	26.69	25.90
G_3 (75% Shade intensity)	21.45	23.16	22.30
G_4 (Polyhouse condition)	28.83	29.33	29.08
G_5 (Open condition)	19.31	19.30	19.30
Mean	23.45	24.63	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.53	0.31	0.69
CD @ 5%	1.63	0.93	NS

4.1.2.2 Effect of hybrid varieties

The length of leaves was differed significantly among two different hybrid varieties of Chinese cabbage at all crop growth stages. Hybrid variety V_2 (Tropical Highland) produced

significantly longest leaves per plant (17.56 cm, 24.63 cm, 27.27 cm and 30.75 cm, respectively) at 15, 30, 45 DAT & at harvest respectively, followed by hybrid variety V_1 (Sun-60) (16.26 cm, 23.45 cm, 26.23 cm and 29.48 cm, respectively).

4.1.2.3 Interaction effect

The interaction effect between growing condition and hybrid varieties on length of leaves was found significant only at fifteen DAT where interaction of Polyhouse with hybrid variety Sun-60 (G_4V_1) was highest (22.6 cm) which was statistically at par with G_4V_2 (21.84 cm).

Table 4.7 Length of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 45 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	V_2 (Tropical Highland)	
G_1 (35% Shade intensity)	25.78	27.41	26.59
G_2 (50% Shade intensity)	28.21	29.22	28.71
G_3 (75% Shade intensity)	24.42	26.41	25.42
G_4 (Polyhouse condition)	31.30	32.51	31.90
G_5 (Open condition)	21.43	20.80	21.12
Mean	26.23	27.27	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.54	0.33	0.74
CD @ 5%	1.65	0.99	NS

Table 4.8 Length of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at harvest

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	V_2 (Tropical Highland)	
G_1 (35% Shade intensity)	29.11	30.65	29.88
G_2 (50% Shade intensity)	30.78	33.06	31.92
G_3 (75% Shade intensity)	28.04	29.3	28.67
G_4 (Polyhouse condition)	33.03	35.05	34.04
G_5 (Open condition)	26.53	26.32	26.42
Mean	29.48	30.75	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.77	0.42	0.95
CD @ 5%	2.37	1.28	NS

4.1.3 Width of leaves (cm)

The data on width of leaves plant^{-1} of Chinese cabbage as influenced by different treatments have been presented in Table 4.9, 4.10, 4.11 and 4.12 for 15, 30, 45 DAT and at harvest and graphically depicted in Fig. 4.

4.1.3.1 Effect of growing conditions

The width of leaves plant^{-1} of Chinese cabbage was differed significantly due to different growing conditions during all the crop growth stages. Significantly the highest width were observed at 15, 30, 45 DAT and at harvest in growing condition G_4 (Polyhouse condition) (12.26

cm, 16.97 cm, 20.43 cm, and 22.96 cm, respectively) which was followed by at 15, 30, 45 DAT and statistically at par at harvest with G_2 (50% Shade intensity) (10.9 cm, 14.41 cm, 17.71 cm and 21.39 cm, respectively) followed by G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition). These results are in confirmative with the earlier findings of Dixit (2007), Garde (2018) in leafy vegetables and Rane (2020) in knol-khol who reported maximum leaf width under polyhouse condition.

Table 4.9 Width of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 15 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	8.72	10.69	9.70
G_2 (50% Shade intensity)	10.31	11.49	10.90
G_3 (75% Shade intensity)	8.54	9.12	8.83
G_4 (Polyhouse condition)	12.74	11.79	12.26
G_5 (Open condition)	7.43	7.49	7.46
Mean	9.55	10.12	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.3	0.16	0.35
CD @ 5%	0.92	0.47	1.05

Table 4.10 Width of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 30 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	13.35	14.33	13.84
G_2 (50% Shade intensity)	13.92	14.89	14.41
G_3 (75% Shade intensity)	12.25	14.16	13.20
G_4 (Polyhouse condition)	17.13	16.81	16.97
G_5 (Open condition)	11.15	10.74	10.95
Mean	13.56	14.19	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.35	0.20	0.44
CD @ 5%	1.09	0.60	NS

4.1.3.2 Effect of hybrid varieties

The width of leaves differed significantly among two different hybrid varieties at all crop growth stages. Hybrid variety V_2 (Tropical Highland) produced significantly broader leaves plant^{-1} (10.12 cm, 14.19 cm, 17.29 cm and 20.80 cm) tailed by hybrid variety V_1 (Sun-60) (9.55 cm, 13.56 cm, 16.50 cm and 19.80 cm) at 15, 30, 45 DAT and at harvest, respectively.

4.1.2.3 Interaction effects

The interaction effect between growing condition and hybrid varieties on width of leaves was found significant only at 15 DAT where the interaction b/w polyhouse and V_1 (Sun-60) *i.e* G_4V_1 was highest (12.74 cm) which was statistically at par with G_4V_2 (11.79 cm).

Table 4.11 Width of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at 45 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	16.59	17.83	17.21
G_2 (50% Shade intensity)	17.19	18.24	17.71
G_3 (75% Shade intensity)	15.29	16.85	16.07
G_4 (Polyhouse condition)	20.37	20.48	20.43
G_5 (Open condition)	13.06	13.06	13.06
Mean	16.50	17.29	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.36	0.22	0.48
CD @ 5%	1.12	0.65	NS

Table 4.12 Width of leaves plant^{-1} as influenced by different growing conditions and hybrid varieties at harvest

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	19.63	21.31	20.47
G_2 (50% Shade intensity)	20.75	22.03	21.39
G_3 (75% Shade intensity)	18.44	19.47	18.95
G_4 (Polyhouse condition)	22.41	23.51	22.96
G_5 (Open condition)	17.78	17.68	17.73
Mean	19.80	20.80	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.51	0.32	0.72
CD @ 5%	1.58	0.97	NS

4.1.4 Plant height (cm)

The periodical data on plant height as influenced by different growing conditions and hybrid varieties are presented in Table 4.13, 4.14, 4.15 and 4.16 for 15, 30, 45 DAT and at harvest, respectively and graphically depicted in Fig. 5.

Table 4.13 Plant height as influenced by different growing conditions and hybrid varieties at 15 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	18.30	21.12	19.71
G_2 (50% Shade intensity)	19.83	22.55	21.19
G_3 (75% Shade intensity)	17.28	18.98	18.13
G_4 (Polyhouse condition)	24.65	24.04	24.34
G_5 (Open condition)	12.90	12.85	12.87
Mean	18.59	19.91	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.53	0.26	0.59
CD @ 5%	1.63	0.80	1.78

Table 4.14 Plant height as influenced by different growing conditions and hybrid varieties at 30 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	25.46	26.94	26.20
G_2 (50% Shade intensity)	26.36	28.36	27.36
G_3 (75% Shade intensity)	24.33	24.98	24.66
G_4 (Polyhouse condition)	30.61	32.19	31.40
G_5 (Open condition)	20.93	20.47	20.70
Mean	25.54	26.59	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.74	0.34	0.75
CD @ 5%	2.27	1.01	NS

Table 4.15 Plant height as influenced by different growing conditions and hybrid varieties at 45 DAT

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	27.86	30.05	28.96
G_2 (50% Shade intensity)	29.22	31.00	30.11
G_3 (75% Shade intensity)	25.90	27.19	26.55
G_4 (Polyhouse condition)	33.04	33.86	33.45
G_5 (Open condition)	23.09	22.95	23.02
Mean	27.82	29.01	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.66	0.39	0.88
CD @ 5%	2.04	1.18	NS

Table 4.16 Plant height as influenced by different growing conditions and hybrid varieties at harvest

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	29.32	30.82	30.07
G_2 (50% Shade intensity)	30.96	32.40	31.68
G_3 (75% Shade intensity)	28.53	30.63	29.58
G_4 (Polyhouse condition)	34.72	35.25	34.98
G_5 (Open condition)	27.77	28.56	28.16
Mean	30.26	31.53	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.67	0.42	0.94
CD @ 5%	2.07	1.27	NS

4.1.4.1 Effect of growing conditions

Plant height in Chinese cabbage was differed significantly due to different growing conditions throughout the crop growth period. Significantly the tallest plants (24.34 cm, 31.40 cm, 33.45 cm and 34.98 cm) were recorded in growing condition G_4 (Polyhouse) at 15, 30, 45

DAT and at harvest, respectively followed by G_2 (50% shade intensity) (21.19 cm, 27.36 cm, 30.11 cm and 31.68 cm, respectively), G_1 (35% shade intensity), G_3(75% shade intensity) and G_5 (open). More vegetative growth under polyhouse condition may be due to congenial micro-climate that prevailed inside the green house. These results are in line with Ramanarao *et al.* (2013) in capsicum, Dixit (2007), Ngullie and Biswas (2016) in capsicum, Singh *et al.* (2019) in brinjal and Yasoda *et al.* (2018) in cauliflower.

4.1.4.2 Effect of hybrid varieties

The plant height in Chinese cabbage was differed significantly among two different hyrid varieties at all crop growth phases. Significantly tallest plants (19.91 cm, 26.59 cm, 29.01 cm and 31.53 cm) were recorded in variety V_2 (Tropical Highland) than V_1 (Sun-60) (18.59 cm, 25.54 cm, 27.82 cm and 30.26 cm) at 15, 30, 45 DAT and at harvest, respectively.

4.1.4.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties was found significant only at 15 DAT where the interaction V_1 (Sun-60) grown under polyhouse (G_4) *i.e*. G_4V_1 was found highest (24.65 cm) which was statistically at par with G_4V_2 (24.04 cm).

4.1.5 Leaf colour

Leaf colour as influenced by genetic characters never shown any significant variation however, due to excess shading in G_3 (75% Shade intensity) both the varieties produced the light green leaves.

Table 4.17 Leaf colour as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties	
	V_1 (Sun-60)	**V_2 (Tropical Highland)**
G_1 (35% Shade intensity)	Dark green	Dark green
G_2 (50% Shade intensity)	Dark green	Dark green
G_3 (75% Shade intensity)	Light green	Light green
G_4 (Polyhouse condition)	Dark green	Dark green
G_5 (Open condition)	Dark green	Dark green

4.1.6 Leaf shape

Leaf shape being a varietal character influenced by genetic characters never shown any significant variation under the different growing conditions.

Table 4.18 Leaf shape as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties	
	V_1 (Sun-60)	**V_2 (Tropical Highland)**
G_1 (35% Shade intensity)	Orbicular	Orbicular
G_2 (50% Shade intensity)	Orbicular	Orbicular
G_3 (75% Shade intensity)	Orbicular	Orbicular
G_4 (Polyhouse condition)	Orbicular	Orbicular
G_5 (Open condition)	Orbicular	Orbicular

4.2 Yield and Yield attributing parameters

4.2.1 Days required for head initiation

The data recorded for number of days required for head initiation in Chinese cabbage as influenced by different growing conditions and hybrid varieties are presented in Table 4.19 and graphically depicted in Fig. 6.

4.2.1.1 Effect of growing conditions

A statistically significant variation was found in number of days required for head initiation in Chinese cabbage with different levels of growing conditions. The significantly minimum days (28.42) for head initiation was recorded in growing condition G_4 (Polyhouse) followed by G_2 (50% shade intensity) (33.60 days), G_1 (35% shade intensity) (34.94 days), G_3 (75% shade intensity) (36.00 days) with maximum days required in G_5 (open) (38.87 days).

Early head initiation in polyhouse might be due to rapid vegetative growth. These results are confirmative with Thapa *et al.* (2013) and Minz (2004) in broccoli who reported the earlier curd initiation in broccoli in polyhouse condition than in open condition.

4.2.1.2 Effect of hybrid varieties

The number of days required for head initiation differed significantly among two hybrid varieties. The earlier head initiation was recorded in hybrid variety V_1 (Sun-60) at 33.68 days whereas variety V_2 (Tropical highland) took more days *i.e.* 35.05 days.

4.2.1.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on number of days required for head initiation was found non-significant.

Table 4.19 Number of days required for head initiation as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	34.33	35.54	34.94
G_2 (50% Shade intensity)	33.12	34.08	33.60
G_3 (75% Shade intensity)	35.70	36.29	36.00
G_4 (Polyhouse condition)	27.50	29.33	28.42
G_5 (Open condition)	37.75	40.00	38.87
Mean	33.68	35.05	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.82	0.45	1.01
CD @ 5%	2.52	1.37	NS

4.2.2 Days required for head formation

The number of days required for head formation in Chinese cabbage as influenced by different growing conditions and hybrid varieties are presented in Table 4.20 and graphically depicted in Fig. 7.

4.2.2.1 Effect of growing conditions

The number of days required for head formation was differed significantly due to different growing conditions. Minimum number of days (30.54) required for head formation was recorded in G_4 (Polyhouse) which was statistically at par with G_1 (35% shade intensity) (33.14 days) and G_2 (50% shade intensity) (33.87 days) which was followed by G_3 (75% shade intensity) and G_5 (open) (35.56 days and 40.59 days, respectively). These results are in confirmation with those reported by Nagalakshmi *et al.* (2001) in cauliflower, Thapa *et al.* (2013) in broccoli and Rane (2020) in knol-khol.

Table 4.20 Days required for head formation as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	31.98	34.29	33.14
G_2 (50% Shade intensity)	32.57	35.17	33.87
G_3 (75% Shade intensity)	34.42	36.71	35.56
G_4 (Polyhouse condition)	30.00	31.08	30.54
G_5 (Open condition)	41.12	40.07	40.59
Mean	34.02	35.46	
	Growing condition	Hybrid variety	Interaction
S.E.±	1.17	1.01	2.26
CD @ 5%	3.59	NS	NS

4.2.2.2 Effect of hybrid varieties

The number of days required for head formation was found non- significant among the hybrid varieties.

4.2.2.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on number of days required for head formation was found non-significant.

4.2.3 Days required for harvest

The number of days required for harvesting as influenced by altered growing conditions and hybrid varieties are presented in Table 4.21 & graphically represented in Fig.8**.**

4.2.3.1 Effect of growing conditions

The number of days required for harvesting was influenced significantly by the different growing conditions. Significantly minimum number of days (58.95) required for harvesting was observed in G_4 (Polyhouse) while open field condition (G_5) recorded the significant delay for harvest (79.47 days). The growing conditions G_1 (35% shade), G_2 (50% shade) and G_3 (75% shade) recorded 105.43, 111.83 and 129.73 days, respectively for harvesting. Similar observations were made previously by Minz (2004) and Thapa *et al.* (2013) in broccoli.

4.2.3.2 Effect of hybrid varieties

The number of days required for harvesting was significantly differed among different hybrid varieties. The minimum number of days (67.70) required for harvesting was recorded in V_1 (Sun-60) whereas variety V_2 (Tropical Highland) took 70.51 days.

4.2.3.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on number of days required for harvesting was found non-significant.

Table 4.21 Days required for harvesting as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	66.31	69.83	68.07
G_2 (50% Shade intensity)	65.69	69.25	67.47
G_3 (75% Shade intensity)	70.12	73.00	71.56
G_4 (Polyhouse condition)	57.50	60.41	58.95
G_5 (Open condition)	78.87	80.06	79.47
Mean	67.70	70.51	
	Growing condition	Hybrid variety	Interaction
S.E.±	1.49	0.93	2.08
CD @ 5%	4.59	2.81	NS

4.2.4 Length of head (cm)

The length of head as influenced by different growing conditions and hybrid varieties is presented in Table 4.22 and graphically depicted in Fig. 9**.**

Table 4.22 Length of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	24.54	26.52	25.53
G_2 (50% Shade intensity)	26.83	27.49	27.16
G_3 (75% Shade intensity)	25.76	26.38	26.07
G_4 (Polyhouse condition)	28.33	29.70	29.01
G_5 (Open condition)	23.19	24.18	23.68
Mean	25.73	26.85	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.62	0.36	0.8
CD @ 5%	1.91	1.08	NS

4.2.4.1 Effect of growing conditions

The length of head was influenced significantly due to different growing conditions. Significantly highest head length (29.01 cm) was recorded in growing condition G_4 (Polyhouse) which was statistically at par with G_2 (50% shade intensity) (27.16 cm) followed by growing condition G_3 (75% shade intensity), G_1 (35% shade intensity) with shortest head found in G_5

(open) which recorded head length of 26.07 cm, 25.53 cm and 23.68 cm, respectively. Laczi *et al.* (2016) in Chinese cabbage also reported similar observation on Chinese cabbage.

4.2.4.2 Effect of hybrid varieties

The head length was differed significantly among two different hybrid varieties. Highest head length (26.85 cm) was found in V_2 (Tropical Highland) whereas it was 25.73 cm in V_1 (Sun-60).

4.2.4.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on head length was found non-significant.

4.2.5 Width of head (cm)

The width of head as influenced by different growing conditions and hybrid varieties is presented in Table 4.23 and graphically depicted in Fig.10**.**

4.2.5.1 Effect of growing conditions

The width of head was influenced significantly due to different growing conditions. Highest head width (12.11 cm) was recorded in growing condition G_4 (Polyhouse) which was statistically at par with G_2 (50% shade intensity) (11.40 cm) and G_1 (35% shade intensity) (11.35 cm) which was followed by G_3 (75% shade intensity) which was 10.70 cm. Lowest head width (10.42 cm) was found in G_5 (open condition). These findings are in agreement with Laczi *et al.* (2016) in Chinese cabbage, Babu and reddy (2017) and Thapa *et al.* (2013) in Broccoli also reported more head width under polyhouse condition whereas, Yasoda *et al.* (2018) reported more head width under 50% shadenet in Cauliflower.

4.2.5.2 Effect of hybrid varieties

The head width was differed significantly among two different hybrid varieties. Highest head width (11.45 cm) was found in V_2 (Tropical Highland) whereas it was 10.93 cm of V_1 (Sun-60).

Table 4.23 Width of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	11.07	11.63	11.35
G_2 (50% Shade intensity)	11.23	11.58	11.40
G_3 (75% Shade intensity)	10.63	10.77	10.70
G_4 (Polyhouse condition)	11.86	12.35	12.11
G_5 (Open condition)	9.89	10.95	10.42
Mean	10.93	11.45	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.26	0.16	0.36
CD @ 5%	0.80	0.48	NS

4.2.5.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on head width was found non-significant.

4.2.6 Average weight of head (g)

The average weight of head as influenced by different growing conditions and hybrid varieties is presented in Table 4.24 and graphically represented in Fig. 11**.**

4.2.6.1 Effect of growing conditions

The average weight of head was influenced significantly due to different growing conditions. Significantly highest average weight of head (694.33 g) was recorded in growing condition G_4 (Polyhouse) which was followed by G_2 (50% shade intensity), G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (571.95 g, 524.39 g, 491.71 g and 456.31 g, respectively). The highest head weight in polyhouse might be due to the highest head length and width of the respective varieties and suitability of physical climate. Similar results were reported by Laczi *et al.* (2016) in Chinese cabbage, Minz (2004), Thapa *et al.* (2013), Babu and Reddy (2017) in broccoli, and Yasoda *et al.* (2018) in cauliflower.

4.2.6.2 Effect of hybrid varieties

The average weight of head was differed significantly due to two different hybrid varieties. Significantly highest average weight of head (564.72 g) was found in V_2 (Tropical Highland) whereas it was 530.76 g in V_1 (Sun-60).

4.2.6.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on average weight of head was found non-significant.

Table 4.24 Average weight of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	506.62	542.16	524.39
G_2 (50% Shade intensity)	555.50	588.41	571.95
G_3 (75% Shade intensity)	485.67	497.75	491.71
G_4 (Polyhouse condition)	667.08	721.58	694.33
G_5 (Open condition)	438.92	473.71	456.31
Mean	530.76	564.72	
	Growing condition	Hybrid variety	Interaction
S.E.±	26.98	8.31	18.58
CD @ 5%	83.15	25.05	NS

4.2.7 Size of head (cm^2)

The size of head as influenced by different growing conditions and hybrid varieties is presented in Table 4.25 and graphically depicted in Fig. 12**.**

4.2.7.1 Effect of growing conditions

The size of head was influenced significantly due to different growing conditions. Significantly highest sized head (351.28 cm^2) was recorded in growing condition G_4 (Polyhouse) which was followed by G_2 (50% shade intensity), G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (308.10 cm^2, 290.70 cm^2, 272.98 cm^2 and 247.87 cm^2, respectively). The highest head size in polyhouse was due to the maximum head length and width of the respective varieties. The results of the present investigation are in conformity with the results of Minz (2004) in broccoli, Laczi *et al.* (2016) in Chinese cabbage and Rane (2020) in knol-khol.

Table 4.25 Size of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	285.04	296.37	290.70
G_2 (50% Shade intensity)	301.38	314.82	308.10
G_3 (75% Shade intensity)	260.54	285.43	272.98
G_4 (Polyhouse condition)	336.34	366.23	351.28
G_5 (Open condition)	230.82	264.92	247.87
Mean	282.82	305.55	
	Growing condition	Hybrid variety	Interaction
S.E.±	10.78	5.35	11.97
CD @ 5%	33.22	16.13	NS

4.2.7.2 Effect of hybrid varieties

The size of head was difffered significantly among two different hybrid varieties. Significantly highest size of head (305.55 cm^2) was found in V_2 (Tropical Highland) whereas it was 282.82 cm^2 in V_1 (Sun-60).

4.2.7.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on average size of head was found non-significant.

4.2.8 Yield per plot (kg)

The yield/plot as influenced by different growing conditions and hybrid varieties is presented in Table 4.26 and graphically depicted in Fig. 13**.**

4.2.8.1 Effect of growing conditions

A statistically significant variation was found in yield per plot of Chinese cabbage with different levels of growing conditions. Significantly highest yield per plot (10.79 kg) was recorded in treatment G_4 (Polyhouse) followed by G_2 (50% shade intensity), G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (8.84 kg, 8.25 kg, 7.71 kg and 7.13 kg, respectively). Similar findings were reported by Minz (2004), Thapa *et al.* (2013) and Babu and Reddy (2017) in broccoli.

4.2.8.2 Effect of hybrid varieties

The yield per plot was differed significantly among two different hybrid varieties. Significantly higher yield per plot (8.81 kg) was produced in V_2 (Tropical Highland) whereas, it was 8.27 kg in V_1 (Sun-60).

4.2.8.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on yield per plot was found non-significant.

Table 4.26 Yield per plot as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	7.97	8.53	8.25
G_2 (50% Shade intensity)	8.49	9.18	8.84
G_3 (75% Shade intensity)	7.64	7.78	7.71
G_4 (Polyhouse condition)	10.37	11.21	10.79
G_5 (Open condition)	6.90	7.36	7.13
Mean	8.27	8.81	
	Growing condition	Hybrid Variety	Interaction
S.E.±	0.41	0.12	0.27
CD @ 5%	1.25	0.36	NS

4.2.9 Yield per hectare (q)

The yield hectare^{-1} as influenced by different growing conditions and hybrid varieties is presented in Table 4.27 and graphically depicted in Fig. 14**.**

4.2.9.1 Effect of growing conditions

A statistically significant variation was found in yield hectare^{-1} of Chinese cabbage with different levels of growing conditions. Significantly the highest yield hectare^{-1} (501.05 q) was recorded in treatment G_4 (Polyhouse) followed by G_2 (50% shade intensity), G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (409.02 q, 381.88 q, 356.88 q and 330.20 q, respectively). Increased yield under polyhouse condition was due to favourable climatic conditions, which led to higher vegetative growth contributing to early head initiation, increased accumulation of food material and increased yield. The results of the present study are in conformity with the results of Laczi *et al.* (2016) in Chinese cabbage Minz (2004), Thapa *et al.* (2013), and Babu and Reddy (2017) in broccoli, Ngullie and Biswas (2016) in capsicum, and Ashok and Ravivarman (2021) in coriander.

4.2.9.2 Effect of hybrid varieties

The yield per hectare was differed significantly among two different hybrid varieties. Significantly more yield per hectare (408.63 q) was found in V_2 (Tropical Highland) whereas, it was 382.98 q in V_1 (Sun-60).

Table 4.27 Yield per hectare as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	368.73	395.02	381.88
G_2 (50% Shade intensity)	393.05	424.99	409.02
G_3 (75% Shade intensity)	353.70	360.06	356.88
G_4 (Polyhouse condition)	479.86	522.25	501.05
G_5 (Open condition)	319.56	340.85	330.20
Mean	382.98	408.63	
	Growing condition	Hybrid variety	Interaction
S.E.±	19.11	5.54	12.40
CD @ 5%	58.88	16.71	NS

4.2.9.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on yield per hectare was found non-significant.

4.2.10 Colour of head

The head colour in both the hybrids of Chinese cabbage never differed due to the effect of different growing conditions. However, the hybrid Tropical Highland (V_2) under open field conditions produced the yellowish green heads which might be due to the effect of direct sunlight.

Table 4.28 Colour of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties	
	V_1 (Sun-60)	**V_2 (Tropical Highland)**
G_1 (35% Shade intensity)	Light green	Whitish green
G_2 (50% Shade intensity)	Light green	Whitish green
G_3 (75% Shade intensity)	Light green	Whitish green
G_4 (Polyhouse condition)	Light green	Whitish green
G_5 (Open condition)	Light green	Yellowish green

4.2.11 Shape of head

The head shape in both the Chinese cabbage hybrids differed due to the influence of growing conditions in which under 35%, and 50% shading and under polyhouse conditions both the hybrids produced cylindrical heads while under 75% shading intensity and open field conditions, the heads produced were of oblong shape. This variation in head shapes might be the result of variation in length and width of the head.

Table 4.29 Shape of head as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties	
	V_1 (Sun-60)	**V_2 (Tropical Highland)**
G_1 (35% Shade intensity)	Cylindrical	Cylindrical
G_2 (50% Shade intensity)	Cylindrical	Cylindrical
G_3 (75% Shade intensity)	Oblong	Oblong
G_4 (Polyhouse condition)	Cylindrical	Cylindrical
G_5 (Open condition)	Oblong	Oblong

4.3 Pest and disease incidence

4.3.1 Aphids

The aphid incidence as influenced by different growing conditions and hybrid varieties are presented in Table 4.30 and graphically depicted in Fig. 15**.**

4.3.1.1 Effect of growing conditions

A statistically significant variation was found for aphid incidence on Chinese cabbage with different levels of growing conditions. Significantly lowest (4.81%) aphid incidence was recorded in treatment G_4 (Polyhouse) followed by G_2 (50% shade intensity) G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (9.94%, 11.89%, 14.09% and 17.44% respectively). Singh *et al.* (2004) in hybrid sweet pepper also reported maximum aphid incidence in open field condition than in protected condition.

Table 4.30 Aphid incidence as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	12.24	11.55	11.89
G_2 (50% Shade intensity)	10.38	9.50	9.94
G_3 (75% Shade intensity)	14.38	13.81	14.09
G_4 (Polyhouse condition)	5.19	4.44	4.81
G_5 (Open condition)	17.77	17.11	17.44
Mean	11.99	11.28	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.62	0.16	0.36
CD @ 5%	1.90	0.48	NS

4.3.1.2 Effect of hybrid varieties

The aphid incidence was differed significantly due to two different hybrid variety. Significantly less aphid incidence (11.28%) was found in V_2 (Tropical Highland) whereas it was 11.99% in V_1 (Sun-60).

4.3.1.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on aphid incidence was found non-significant.

4.3.2 Caterpillar

The caterpillar occurrence as influenced by dissimilar growing conditions and hybrid varieties are presented in Table 4.31 and graphically depicted in Fig.16**.**

4.3.2.1 Effect of growing conditions

A statistically significant variation was found in caterpillar incidence of Chinese cabbage with different levels of growing conditions. Significantly lowest (9.06%) caterpillar incidence was recorded in treatment G_4 (Polyhouse) followed by G_2 (50% shade intensity), G_1 (35% shade intensity), G_3 (75% shade intensity) and G_5 (open condition) (15.72%, 20.96%, 25.15% and 27.35% respectively). Singh *et al.* (2004) in hybrid sweet pepper also reported maximum pest incidence in open field condition than in protected condition.

4.3.2.2 Effect of hybrid varieties

The caterpillar incidence was differed significantly among two hybrid varieties. Significantly more caterpillar incidence (20.16%) was found in V_1 (Sun-60) whereas it was 19.13% of V_2 (Tropical Highland).

Table 4.31 Caterpillar incidence as influenced by different growing conditions and hybrid varieties

Growing condition	Hybrid varieties		Mean
	V_1 (Sun-60)	**V_2 (Tropical Highland)**	
G_1 (35% Shade intensity)	21.56	20.36	20.96
G_2 (50% Shade intensity)	16.50	14.94	15.72
G_3 (75% Shade intensity)	25.75	24.54	25.15
G_4 (Polyhouse condition)	9.38	8.75	9.06
G_5 (Open condition)	27.62	27.08	27.35
Mean	20.16	19.13	
	Growing condition	Hybrid variety	Interaction
S.E.±	0.63	0.27	0.60
CD @ 5%	1.94	0.81	NS

4.3.2.3 Interaction effect

The interaction effect between growing conditions and hybrid varieties on caterpillar incidence was found non-significant.

4.3.3 Disease incidence

There was no disease incidence observed in any of the growing conditions in Chinese cabbage during winter season of 2019-20 under investigation.

5. SUMMARY AND CONCLUSIONS

An experiment entitled "Performance of Chinese cabbage hybrids under different growing conditions" was carried out during winter 2019 to evaluate the performance of Chinese cabbage hybrids in terms of growth parameters, yield and yield attributing parameters under Polyhouse, 3 different Shadenets (*viz.* 35%, 50% and 75% Shade intensity) and Open field condition. Two varieties *viz.* Sun-60 and Tropical Highland were used for the experimental research.

5.1 Summary

5.1.1 Effect of growing conditions

The key findings as regards to growth characters, yield and yield contributing characters & pest and disease incidence in Chinese cabbage under different growing conditions are summarized here.

Number of leaves, leaf length, leaf width and plant height were significantly influenced by different growing conditions. Plants in Polyhouse condition (G_4) recorded maximum numbers of leaves (20.92), leaf length (34.04 cm), leaf width (22.96 cm) and plant height (34.98 cm) whereas plants in G5 (open) recorded minimum leaf numbers (15.06), leaf length (26.42 cm) leaf width (17.33 cm) and plant height (28.16 cm) at harvest.

In respect of leaf colour, at G_1 (35% shade intensity), G_2 (50% shade intensity), G_4 (Polyhouse) and G_5 (open condition), dark green colour were observed, while at G_3 (75% shade intensity) light green colour was observed.

Days required for head initiation and days required for head formation were significantly influenced by different growing conditions. Plants in treatment G_4 (Polyhouse conditions) recorded minimum (26.42) days for head initiation and (30.54) days for head formation while maximum days *i.e.* 38.87 and 40.59 were required for head initiation and head formation respectively in treatment G_5 (open condition). Days recorded for harvesting were differed significantly by different growing conditions. Plants in treatment G_4 (Polyhouse conditions) recorded minimum (58.95) days for harvesting while maximum (79.47) days required for harvesting was recorded in treatment G_5 (open condition).

The significantly highest head length, head width, average weight and size of head *i. e.* 29.01 cm, 12.11 cm, 694.33 g and 351.28 cm^2 respectively were recorded in growing condition G_4 (Polyhouse) which was statistically at par with G_2 (50% shade intensity). Minimum head length, width, average weight and size of head were recorded in G_5 (open condition).

The effect of different growing conditions was found significant on yield per plot and per hectare. Highest yield per plot (10.79 kg) and per hectare (501.05 q) were recorded in G_4 (Polyhouse). Minimum yield per plot (7.13 kg) and per hectare (330.20 q) were recorded in treatment G_5 (open condition).

In respect of head colour at G_1 (35% shade intensity), G_2 (50% shade intensity), G_3 (75% shade intensity) and G_4 (Polyhouse) light green and whitish green coloured head were found but in G_5 (open) light green and yellowish green coloured head were noticed.

In respect of shape of head, at G_1 (35% shade intensity), G_2 (50% shade intensity) and G_4 (Polyhouse) cylindrical shaped head were observed while in G_3 (75% shade intensity) and G_5 (open) oblong shaped head were found.

The highest per cent of aphid and caterpillar incidence *i.e.* 17.44 and 27.35 respectively were observed in G_5 (Open field conditions) while the lowest per cent of aphid and caterpillar incidence *i.e.* 4.81 and 9.06 respectively were observed in G_4 (Polyhouse).

5.1.2. Effect of hybrid varieties

The highest number of leaves (17.20), maximum leaf length (30.75 cm) were recorded in hybrid variety V_2 (Tropical Highland) whereas, minimum leaf number (16.21) and length of leaves (29.48 cm) were observed in V_1 (Sun-60) at harvest.

The broadest leaves (31.53 cm) and maximum growth in respect of plant height (20.80 cm) was recorded in V_2 (Tropical Highland). While minimum leaf width (19.80 cm) and plant height (30.26 cm) were observed in V_1 (Sun-60) at harvest.

In respect of leaf colour, both the hybrid varieties produced Dark green coloured leaf except in G_3 (75% shade intensity) light green coloured leaves were produced.

The least days required for head initiation (33.68 days) was recorded in V_1 (Sun-60) whereas it was maximum days (35.05 days) in V_2 (Tropical Highland).

Number of days required for head formation was found non- significant among the hybrid varieties. The number of days required for harvesting was significantly influenced due to different hybrid varieties. The minimum number of days (67.70) required for harvesting was recorded in V_1 (Sun-60) whereas variety V_2 (Tropical Highland) took 70.51 days.

Highest head length (26.85 cm) and maximum width of head (11.45 cm) were as found in V_2 (Tropical Highland) whereas it was lowest 25.73 cm and 10.93 cm for head length and head width respectively in V_1 (Sun-60).

The average weight of head as well as size of head was influenced significantly due to two different hybrid varieties. Significantly highest average weight of head (564.72 g) and size of head (305.55 cm^2) was found in V_2 (Tropical Highland) whereas it was lowest 530.76 g and 282.82 cm^2 of V_1 (Sun-60).

Hybrid variety V_2 (Tropical Highland) recorded maximum yield per plot (8.81 kg) and per hectare (408.63 q) whereas minimum yield per plot (8.27 kg) and per hectare (382.98 q) was recorded in hybrid variety V_1 (Sun-60).

In respect of head colour, hybrid variety V_1 (Sun-60) produced light green coloured heads whereas V_2 (Tropical Highland) produced whitish green coloured heads in all conditions except in open condition where yellowish green coloured heads were produced.

In respect of head shape, both the hybrid varieties produced cylindrical heads on all conditions except on 75% shade intensity and open condition where oblong shaped heads were produced.

The highest per cent of aphid and caterpillar incidence *i.e.* 11.99% and 20.16% respectively were observed in V_1 (Sun-60) whereas the lowest per cent of aphid (11.28%) and caterpillar (19.13%) incidence was observed in V_2 (Tropical Highland).

5.1.3 Interaction effect

Interaction effect of growing conditions and hybrid varieties was found significant only for length of leaves, width of leaves and plant height at 15 DAT.

The interaction effect between growing condition and hybrid varieties on length of leaves and width of leaves was found significant only at 15 DAT where interaction of Polyhouse with hybrid variety Sun-60 (G_4V_1) was highest (22.6 cm and 12.74 cm) which was statistically at par with G_4V_2 (21.84 cm and 11.79 cm). The interaction effect between growing conditions and hybrid varieties was found significant only at 15 DAT where the interaction between polyhouse (G_4) and V_1 (Sun-60) *i.e* G_4V_1 was found highest (24.65 cm) which was statistically at par with G_4V_2 (24.04 cm).

5.2 Conclusions

The Polyhouse condition (G_4) accompanied with hybrid variety V_2 (Tropical Highland) significantly increased all growth attributes *viz.* number of leaves per plant (20.92, 17.20), leaf length (34.04 cm, 30.75 cm), leaf width (22.96 cm, 20.80 cm) and plant height (34.98 cm, 19.91 cm) and yields attributes *viz.* days required for head initiation (28.42 days), days required for head formation (30.54 days), days required for harvest (58.95 days), length of head (29.01 cm, 26.85 cm), width of head (12.11 cm, 11.45 cm), average weight of head (694.33 g, 564.72 g), size of head (351.28 cm^2, 305.55 cm^2), yield per plot (10.79 kg, 8.81 kg) and yield per hectare (501.05 q, 408.63 q) of Chinese cabbage when compared to other growing conditions and other hybrid variety. Due to high temperature & low humidity disease occurrence was not recorded.

Based on 1 year of investigation it could be concluded that growing of Chinese cabbage under Polyhouse condition and hybrid variety Tropical Highland was found most suitable for achieving higher yield during rabi season.

The above outcomes based on 1 year data and it appears valuable to continue assessment at different places with dissimilar growing conditions and hybrid varieties in future for approval of the above outcomes.

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