PERFORMANCE EVALUATION OF UNDERUTILIZED EDIBLE *ALLIUMS*

By

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(2019-12- 001)

THESIS

Department of Plantation crops and Spices

COLLEGE OF AGRICULTURE
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA
2021

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Submitted in partial fulfilment of the requirement for the degree of

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Department of Plantation crops and Spices

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2021

DECLARATION

I, **Pooja A. E. (2019-12-001**) hereby declare that this thesis entitled **"Performance evaluation of underutilized edible *Alliums*"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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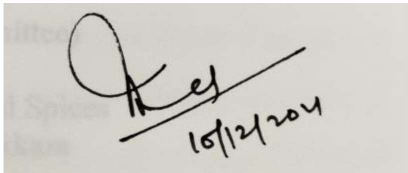
Certified that the thesis entitled **"Performance evaluation of underutilized edible *Alliums*"** is a record of research work done independently by **Pooja A. E. (2019-12-001)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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Errors and omissions are entirely unintentional.

Pooja. A. E.

Pooja A. E.

Dedicated to my guide

and lovely family

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LIST OF SYMBOLS/ NOTATIONS

%	Per cent
/	Per
µ	Micron
µl	Micro liter
Avg.	Average
℃	Degree Celsius
Cm	Centimeter
cm^2	Square centimeter
et al.	and others/ and co-workers
Etc.	And so on; other people / things
Ex	Example
Fig.	Figure
G	Gram
H_0	Null hypothesis
Ha	Hectare
H_A	Alternate hypothesis
Hrs	Hours
i.e.	That is
Kg	Kilogram
Kg/ha	Kilogram per hectare
L^{-1}	Per liter
m^2	Meter square
max.	Maximum
Mg	Milligram
Min	Minute
min.	Minimum
Mm	Millimeter
MT	Metric tonnes
No.	Number
NS	Non-significant
$Plant^{-1}$	Per plant
Q	Quintal
Qha^{-1}	Quintal per hectare
S	Second
S	Significant
SE (d)	Standard error of difference
Sl. No.	Serial number
Temp.	Temperature
viz.	Namely
Wt.	Weigh

LIST OF ABBREVIATIONS

1D	One dimensional
2D	Two dimensional
$Alcl_3$	Aluminium chloride
ANOVA	Analysis of variance
$Bacl_2$	Barium chloride
CD	Critical difference
CE	Catechin equivalent
CRD	Completely randomized design
CV	Coefficient of variation
Df	Degrees of freedom
DNPH	Dinitrophenyl hydrazine
DW	Dry weight
f.m.	Fresh matter
FCR	Folin ciocalteau reagent
FW	Fresh weight
FYM	Farm yard manure
GAE	Gallic acid equivalent
GC-MS	Gas chromatography–mass spectrometry
H_2SO_4	Sulfuric acid
HCl	Hydrochloric acid
HDPE	High density poly ethylene
HPLC	High-performance liquid chromatography
ICAR	Indian council of agricultural research
K	Potassium
LDPE	Low density poly ethylene
MIX	Combination of VC, NC, FYM, PM
MSI	Membrane stability index
Na_2CO_3	Sodium carbonate
$NaNO_2$	Sodium nitrite
NaOH	Sodium hydroxide
NC	Neem cake
NMR	Nuclear magnetic resonance
P	Phosphorous
PET	Polyethylene terephthalate
PLW	Physiological loss of weight
PM	Poultry manure
RWC	Relative water content
SD	Standard deviation
Se	Selenium
TSS	Total soluble solid
VC	Vermicompost
ZECC	Zero energy cool chamber

Introduction

1. INTRODUCTION

Allium L. is one of the largest genera in the Amaryllidaceae (Friesen *et al*., 2006; Fritsch *et al*., 2010; Li *et al*., 2010), with around 900 species (Seregin *et al*., 2015), and it is one of the oldest cultivated vegetables. The genus *Allium* is named after the Latin word for onion (*Allium cepa)*, which means "cultivated onion" and it was originally described by Linnaeus in 1753. The genus *Allium* has long been used by the human in cooking. Onion (*Allium cepa* L.), garlic (*Allium sativum* L.), and leek (*Allium porrum* L.) were all cultivated in Egypt around the fifth and fourth century BC, according to sculptural and painted depictions. This suggests that some of these plants were domesticated as crops at that time. Humans have been attracted to *Allium* plants for thousands of years due to their flavour, taste, therapeutic benefits, and ornamental value.

Allium species and members of Amaryllidaceae family are widespread and diverse, adapted to a wide range of habitats from shady forests to open habitats such as meadows, steppes, deserts, and highlands, and are thus well suited as study objects in studies of plant adaptations to various sun irradiation levels and other geophysical factors (Vvedensky, 1935; Wendelbo, 1971). The genus *Allium* is found naturally in the northern hemisphere and South Africa, primarily in dry climates (De Sarker *et al*., 1997; Friesen *et al*., 2006; Nguyen *et al*., 2008; Neshati and Fritsch, 2009) and temperate zones. On the subtropics and tropics, certain *Allium* species thrive in mountains or highlands, such as in Sri Lanka, Ethiopia, and Central America (Hanelt, 1990; Fritsch and Friesen, 2002). In the western portion of North America, there is a second, less obvious centre of species richness (Fritsch and Friesen, 2002). There are around 30 wild species in India's gene centre, most of which are restricted to the Himalayas (Negi and Pant, 1992). Several kinds of *Allium* may be found in the Himalayas. For the first time, Hooker (1892, 1947) gathered information on *Allium* species and included its 27 species in the flora of British India. The *Allium* species have been identified in the Indian Himalayas and surrounding areas by various researchers: 11 species by Duthie (1906); (ii) 12 species by Blatter (1927-29); (iii) 32 species by Hooker amended and added by

Stearn (1947); (iv) 41 species by Nasir (1975); (v) 36 species by Karthikeyan *et al*. (1989).

Allium species may differ in appearance and flavour, yet biochemically, they are quite similar. The high carbohydrate, vitamin, and mineral content of *Allium* species distinguishes them (Mahajan *et al*., 2015). Flavonols are abundant in *Allium* species (Horbowicz and Kotlinska, 1998). They also include sulphur compounds such as di-propyl di-sulfide and di-propyl trisulfide, polyphenols, total flavonoids, ascorbic acid, and pyruvic acid, among other things. These chemicals give these veggies their antioxidant and antibacterial properties (Štajner *et al*., 2008). Allicin is an organosulphur molecule that gives onions and garlic their distinctive fragrance. Dialyl disulfide and diallyl trisulfide, two allicin derivative compounds, have demonstrated antibacterial and antioxidant activity.

In the Western Himalayas, *Alliums* are used as a spice/condiment in curries, as well as a vegetable and bulb for flavouring salads. Salad seasoning has been confirmed by field surveys and research investigations. In the Himalayan areas of Garhwal and Kumaon, field surveys and research investigations have confirmed that wild *Allium* species may be used for culinary purposes (Negi and Gaur, 1991). In general, all plant components of *Allium* are consumed as raw or cooked vegetables by humans. Many wild species are utilised as spices/ condiments in curries, young leaves as vegetables, and bulbs for flavouring salads in the Western Himalaya. Many wild *Allium* species (11 species) are valuable for food, taste, and medicinal purposes (Mahajan *et al*, 2015). Dried bulbs, leaves, buds, and flowers of a few wild *Allium* species (*Allium auriculatum*, *Allium carolinianum*, *Allium griffithianum*, *Allium hummile*, *Allium roylei*, and *Allium wallichii*) are in high demand.

Allium tuberosum (Chinese chive) is a plant that is native to Central Asia and Europe, but it may now be grown in any part of the world. *A. tuberosum* is a common culinary ingredient as well as an edible vegetable in most parts of the world (Gao *et al*., 2018). The Chinese chive is a perennial plant with rhizomes that produce robust branches. Green leaves are mainly used, but flower buds and scapes are also utilised. Leaves that have been blanched or etiolated are occasionally used. In commercial propagation, Chinese chive is usually propagated via seeds, but it can also be propagated by dividing clumps (Fujime *et al*. 2012). The plant is valued not only as a vegetable and spice, but also for its excellent therapeutic and medicinal significance in folk medicine for nocturnal emissions, abdominal pain, diarrhoea, sexual dysfunction, asthma, gastric ulcer, dyspepsia, and supporting appropriate kidney function (Fang *et al*., 2015; Jiangsu New Medicinal College, 1979). *A. tuberosum* and its chemical constituents have been credited with anticancer, antioxidant, aphrodisiac, and nematicidal characteristics in recent pharmacological research (Huang *et al*., 2016; Hong *et al*., 2014; kim *et al*., 2008; Lee *et al*., 2009).

The Chinese jiaotou (*Allium chinense* G. Don), often known as rakkyo, oriental onion, is a traditional Chinese vegetable native to China (Yan *et al*., 2009; Wang *et al*., 2019) and has been used as a spice food and as a remedy for a variety of diseases including heart problems, headache, worms and tumors in traditional Chinese medicine for over 2000 years (Mann and Stearn, 1960). This crop is usually vegetatively propagated because of its sterility. Pickles have been reported to be made from *Allium chinense* bulbs (Gohil and Koul, 1981). Because of its mild, fresh flavour, *A. chinense* is frequently pickled and served as a side dish in Japan and Vietnam to balance out the stronger flavours of other ingredients in a meal. In Japan, the Chinese onion is a valuable cash crop. It is a perennial plant that tillers profusely and produces a small-ovoid bulb at the base of each shoot (Tanaka *et al*., 2018).

The most common *Allium* species are *Allium cepa* (onion) and *Allium sativum* (garlic), both of which are grown as vegetables and for culinary purposes throughout the country and around the world. Drought, waterlogging, and a variety of diseases and pests cause severe damage to onions and garlic. This has an impact on the yield and leads to price swings. Due to excessive water logging, onion prices are primarily influenced during the kharif season. During the kharif season, market demand for onions surges, causing price hikes. *Allium* species that are underutilised can be an excellent substitute for onion and garlic production in different regions of India, due to their wider adaptability and multipurpose usage, especially under the current unpredictable climatic conditions. Wild alliums are available in both fresh and processed forms. Wild *Allium* species that are widely used might contribute a variety of biochemical components to the human diet. There is no information available on the content of nutritional and bioactive components of these wild, underutilised *Alliums*. For distinct *Allium* characteristics, there is also a broad range of variability. The need of the hour is biochemical analysis of quality components, antioxidants, flavonols, and other flavonoids in these *Allium* species, as well as detailed characterization and evaluation for novel traits such as cold hardiness, disease resistance, and pungency level, as well as crossability with cultivated species (Verma *et al*., 2008). Traditional food plants offer a number of benefits, particularly in terms of domestic food security. They enhance the food supply and provide diversity to the diet, in addition to widening the dietary basis. The agro climate of Kerala is largely not congenial for the commercial cultivation of onion and garlic. It is in this context, the current experiment entitled **Performance evaluation of underutilized edible *Alliums*** was taken up with the broad objective of morphological characterization and biochemical analysis of underutilised edible *Alliums* namely *Allium tuberosum* and *Allium chinense* under Kerala conditions and to standardise the storage methods.

Review of literature

2. REVIEW OF LITERATURE

Onion and garlic are two of the most important bulbous crops that have been grown around the world since antiquity. The rising expense of commercial agriculture, as well as the prevalence of several biotic and abiotic challenges in recent years, has resulted in a 30-50 percent drop in crop yield in onion and garlic across seasons, as well as a multi-fold increase in price. Price changes cause major challenges for both producers and consumers amidst crop failure. Underutilized *Allium* genotypes are an important source of biochemical components, vitamins, and minerals, making them an important part of achieving nutritional security. During crop failures, underutilized *Allium spp*. can be used as a supplement to onion and garlic. The available literature on underutilized edible *Alliums* has been gathered and reviewed in this chapter under the following parameters:

2.1 Morphological parameters

2.2 Yield parameters

2.2 Physiological parameters

2.3 Biochemical parameters

2.5 Storage parameters

2.6 Effect of growing condition

2.1 Morphological parameters

Variability in morphological features of garlic was described by Tripathi *et al*. (2011). The morphological parameters of nine garlic cultivars and twenty-five germplasm lines were studied in an experiment at the ICAR-DOGR Rajgurunagar, Pune. Bulb shape, bulb weight, bulb colour, number of cloves per bulb, equatorial and polar diameter of bulbs, clove colour, clove arrangement, clove length and clove breadth expressed variability among the genotypes.

Khosa *et al*. (2014) investigated 35 *Allium* species accessions for a variety of characteristics, including foliage colour, foliage attitude, density of leaves, degree of leaf waxiness, cross section of leaf, storage organ, bulb skin colour, shape of mature dry bulbs, seed coat colour, number of leaves per plant, leaf length, leaf girth, and plant height. Bulb colour and form of mature dried bulbs showed a high amount of diversity. All of the quantifiable characters showed significant variability. In principal component analysis plots based on morphological features, the diverse *Allium* species exhibited a lot of overlap.

In garlic, Pansey *et al*. (2013) found that analysis of variance (mean square) revealed extremely significant variation for all characteristics except leaf width (4th leaf), indicating that the germplasm has more variability. For pseudostem diameter, days to maturity, polar diameter of bulb, equatorial diameter of bulb, average weight of 10 cloves, and plant height, high estimates of heritability were obtained.

Sharma *et al*. (2015) conducted an experiment during the kharif season to evaluate eleven genotypes of onion. Number of leaves, plant height, bulb weight, marketable yield, collar thickness, percentage of marketable bulb, total soluble solids, total yield, bolting % and doubling percentage were all recorded. The plant height was recorded at its greatest in ASRO-1275 (61.5cm) and lowest in ASRO-1203 (54.4cm) according to the growth and yield character study. ASRO-1273 (218.9q/ha) had the highest marketable yield while ASRO-1215 (107.0q/ha) had the lowest. The proportion of marketable bulbs was highest in ASRO-1201 (89.2%) and lowest in ASRO-1215 (59.4 percent) and ASRO-1273 (248.2q/ha) had the highest total bulb yield, whereas ASRO-1215 (127.4q/ha) had the lowest.

Chuda *et al*. (2015) conducted research on plant morphology, number of leaves per plant, length of first three leaves, number of bulbs per plant, length of stem, diameter of stem, length of inflorescence, length of flower stem, microsporogenesis, pollen viability, and female gametophyte were studied in interspecific F1 *A. cepa* x *A. roylei* hybrids, and found that the majority of morphological characteristics of the F1 hybrids were intermediate to those of the parental accessions.

Genetic diversity in germplasm collection of onion was investigated by Hanci *et al*. (2015). PCA was used to analyse ninety-six accessions of onion obtained from various locations of Turkey for thirty-one quantitative characteristics. Total variance % was highest in PC-I (24.98), followed by PC-II (10.50), and PC-III (7.52). The bulb weight (0.33) and pseudostem diameter (0.33) were the characteristics that contributed more favorably to PC-I.

Neffati (2015) investigated the genetic diversity and phenotypic variability of *Allium roseum* wild populations. The purpose of this study was to determine the phenotypic diversity and germination methods of *A. roseum* from several bioclimatic zones of Tunisia. The major findings demonstrate that bulb germination ability is extremely poor, with germination rates of less than 30% for all accessions tested. The presence of a substantial interaction between the reproduction method and the environmental variables confirms that seedling emergence variation in the field is an adaptation indication to aridity and drought. The findings of this study revealed that the accessions analyzed have a lot of morpho phenological variability. Leaves number, leaf average width, unfolding of final leaf, unfolding of last floral bud, basis stem diameter, number of umbels per plant, umbel width, umbel diameter, and floral stem diameter can be utilized as suitable descriptors to define various *Allium roseum* populations. Furthermore, the factors presented in the paper may make the local population suitable for use as parent material in future breeding programs.

Jafari *et al*. (2017) assessed 15 wild *Allium* accessions (4 *A. elburzense* and 11 *A. akaka*) obtained in the northwestern region of Iran using 16 qualitative and quantitative characteristics. Leaf length, inflorescence diameter, umbel flower number, leaf dry weight, bulb fresh weight, seed length, seed width and weight of 100 seeds exhibited strong heritability. Leaf length, leaf dry weight, inflorescence diameter, flower number in umbel, bulb fresh weight, and weight of 100 seeds all exhibited 92.52 percent variability using PCA. Seed length and seed width accounted for 64.74 percent of the total variation observed.

Islam *et al*. (2004), Panse *et al*. (2013), Mishra *et al*. (2013), Umamaheswarappa *et al*. (2014), Tripathi and Karunakaran (2015), Sharma *et al*. (2015), and Raja *et al*. (2017) all observed large variations in garlic plant height. In research conducted by Tripathi and Karunakaran (2015) in the Kodagu region of Karnataka, garlic variety Bhima Omkar had the shortest plant height (38.9 cm). Under Allahabad agro-climatic conditions, Mishra and Vikram (2017) measured plant height 120 days after garlic clove germination and found a maximum plant height of 62.4 cm in genotype Yamuna Safed-3. In onions, the variation in height was shown to be primarily due to the cultivar's genetic potential as well as environmental conditions, mainly temperature and photoperiod (Tesfay *et al*., 2011).

The variability in number of leaves per plant in garlic was examined by Agarwal and Tiwari (2005), Mishra *et al*. (2013), Panse *et al*. (2013), Umamaheshwarappa *et al*. (2014) and Sharma *et al*. (2015). Islam *et al*. (2004), Tripathi and Karunakaran (2015), on the other hand, found no significant differences in this parameter amongst garlic genotypes.

2.2 Yield parameters

Between 2010 and 2014, Adamczewka *et al*. (2016) conducted a field study on garlic chives (*Allium tuberosum* Rottl. EX spreng). According to the research, leaf yields in 2013 were on average 32.8 percent greater than in 2011 and 2012. The greater yield (17.99 t/ha) was observed in 2013 as a result of mild temperatures and higher total rainfall in the first part of the plant growth season.

At ICAR-DOGR, Mahajan *et al*. (2016) worked on wild *Allium* collection, conservation, and documentation with 30 distinct *Allium* species from India (17 species) and other countries (13 species). Flowering, number of tillers per plant, leaf features, shape, presence of wax, and other characteristics were assessed in all 139 accessions. The palatability of the leaves of nine *Allium* species was tested in order to see if they might be used as a vegetable. *Allium tuberosum* line All – 1587 and *Allium tuberosum* Rott. Kuichi line CGN- 16373 produced consistent yields throughout the growing season, making them ideal for year-round cultivation and potentially serving as a nutritional replacement for onions and garlic.

2.3 Physiological parameters:

2.3.1 Chlorophyll ‘a’ content and chlorophyll ‘b’ content

Stajner and Varga (2003) measured the chlorophyll content of leaves from several wild *Allium* species. Chlorophyll ‘a' and ‘b' content were highest in *Allium ursinum* L. leaves (2.87 mg/g and 1.35 mg/g, respectively), and lowest in *Allium pskemense* L. leaves (0.39 mg/g and 0.11 mg/g, respectively).

2.3.2 Total chlorophyll content

Adamczewka *et al*. (2016) conducted a field study on garlic chives (*Allium tuberosum* Rottl. EX spreng) at Wroclaw University of Environmental Science. The chlorophyll content of chive leaves was determined to be 422.3 mg/kg.

2.3.3 Total carotenoids

Carotenoids are lipid-soluble pigments that are part of photosynthesis complexes (Croce *et al*., 1999a, 1999b). They function as photo protectants by channeling photons to the photosynthetic reaction centre and neutralizing harmful free radicals (Croce *et al*., 1999b; Niyogi, 1999). Carotenoid synthesis is largely conserved across all plant species, and it is often found in leafy tissues. Physiological, metabolic, and genetic variables interact with the developing environment to impact carotenoid accumulation in plant tissue (Chenard *et al*., 2005; Kopsell *et al*., 2003, 2004, 2005).

In the leaf tissues of *A. fistulosum* (cultivar not mentioned), total carotenoids were found to be 2.87 mg/g FW (Stajner *et al*., 2006).

Umehara *et al*. (2006) found 4.63 mg/100 g FW of β-carotene in the leaves of *A. fistulosum* L. cv. Kujyoasagikei.

Twelve USDA-ARS accessions of *Allium fistulosum* were field grown in Knoxville, TN, and Geneva, NY, during the summer of 2007. Pigments were evaluated in leaf and pseudostem tissues using high-performance liquid chromatography. Growing site and accession had little effect on carotenoid and chlorophyll pigments in leaf tissue. *A. fistulosum* has an average of 0.60 mg/100 g FW of β- carotene and 1.14 mg/100 g FW of lutein + zeaxanthin, according to the USDA Nutrient Database, 2008.

2.3.4 Dry matter content

According to Dyduch and Najda (2000), the dry matter content of young garlic leaves ranged from 10.68 to 15.82 percent.

Khalid *et al*. (2014) found no statistically significant differences in dry matter between *Allium tuberosum* (33.47±0.94%) and *Allium sativum* (32.73±0.84%).

Garlic chives (*Allium tuberosum* Rottl. EX spreng) recorded 107.3 percent dry matter, according to Adamczewka *et al*. (2016). In comparison to other *Allium* genus veggies, garlic chives had more dry matter.

2.3.5 Moisture content

Khalid *et al*. (2014) found a substantial variation in moisture content in *Allium sativum* samples, ranging from 62.19±0.82% to 64.07±0.81%.

Akinwande *et al*. (2015) tested three varieties of fresh onion bulbs for moisture content, as well as a garlic clove. The moisture content of garlic was determined to be 76.93 percent, whereas the three onion cultivars had moisture content ranging from 86.60 to 88.67 percent. Garlic had a lower moisture content than onion, indicating that it may be stored for longer periods of time.

2.4 Biochemical parameters

Because of its functions as flavoring agents, antioxidants, aroma, and medicines, edible *Alliums* are extremely important (Stajner *et al*., 2006). Sulphur-containing chemicals and their derivatives are responsible for *Allium* species' antioxidant action. Other bioactive substances such as phenols, flavonoids, microelements, pyruvic acid, and dietary fibre are also present in *Allium* (Nencini *et al*., 2007). *Allium* species are also high in vitamins, particularly vitamin B and vitamin C, minerals, including P, K, and Se (Rekowska and Skupien, 2009), and non-volatile compounds.

2.4.1 Ascorbic acid

Stajner and Varga (2003) examined the amount of ascorbic acid in the leaves of several wild *Alliums*. They found the maximum quantity of vitamin C in the leaves of *Allium schenoprasum* L. (0.811 mg/g), followed by *Allium flavum* L. (0.344 mg/g), *Allium vienale* L. (0.253 mg/g), and *Allium cepa* L. (0.005 mg/g).

Between 2010 and 2014, Adamczewka *et al*. (2010) did a field experiment on garlic chives (*Allium tuberosum* Rottl. EX spreng) at Wrocllaw University of Environmental Science and found that it maintained 540.9 mg/kg of vitamin C.

The ascorbic acid content of onion and garlic was compared by Akinwande *et al*. (2015). Three onion cultivars, Red Creole, Dan Zaria, and White Creole bulb, were compared against garlic cloves in this experiment. Onion cultivars showed greater vitamin C levels ranging from 14.67 to 20.67 mg/100g, whereas garlic had the lowest value of 8 mg/100g fresh weight.

Under the influence of several biofertilizers and minerals, the ascorbic acid content of Yamuna Safed-3 varied from 7.67 mg/100g to 15.60 mg/100g (Choudhary *et al*., 2015).

In a field trial of comparing organic to conventional farming onion production, Thangasmy *et al*. (2018) found that the ascorbic acid content was considerably enhanced following FYM treatment – 13.3mg/100g, MIX - 13.3MG/100g (30.4%) and vermicompost 12.5mg/100g (22.5%) when compared to control.

2.4.2 Phenol

Phenols are bioactive aromatic compounds. Multiple biological characteristics have been documented, including antioxidant, antibacterial, antiviral, anti-inflammatory and antimutagenic effects (Pratt, 1992 and Duthie, 2000).

Total polyphenol levels were measured in three onion cultivars by Lachman *et al*. (2003). Temperature impacts on these components throughout a 36-week storage period were also investigated. Half of the samples were kept at a refrigerator temperature of +4℃, while the other half were kept at a laboratory temperature of +22℃. The red variety Karmen had the highest polyphenolic compounds (108,300 mg/kg DM), the white variety Ala had the least (26,445 mg/kg DM), and the yellow variety Vetana had the average concentration of total polyphenolic compounds (65,210 mg/kg DM). In red and yellow kinds, total polyphenols increased with storage, especially when stored at a laboratory temperature (22°C).

Mahajan *et al*. (2011) examined the biochemical composition of indigenous and foreign onion and garlic cultivars in Pune. The phenol content of 18 onion and 12 garlic cultivars was estimated. They observed that onion cultivars had a higher phenol content (10.3 mg/g fresh wt.) than garlic varieties (4.2 mg/g fresh wt.). Exotic onions had greater phenol content (14.4mg/g) than Indian cultivars (8.89mg/g).

The total phenolic contents of *Allium tuberosum* and *Allium sativum* were compared by Khalid *et al*. (2014). When compared to *Allium sativum* (0.39+0.10 mg GAE/g FW), *A. tuberosum* had greater quantity of phenolic contents (0.61+0.10 mg GAE/g FW).

The total phenolic content of onion, garlic, leek, shallot, chive, and Chinese chive was studied by Mnayer *et al*. (2014). The shallot extracts had the greatest phenol concentration (17.18 mg/g fresh weight), according to the researchers. Onion, garlic, leek, chive and chinese chive had phenol contents of 3.29, 5.61, 10.79, 6.76 and 4.24 mg/g fresh weight, respectively. The phenol content of leek extracts was also observed to be high.

Arfa *et al*. (2015) studied ten Tunician *Allium ampeloprasum* accessions gathered from various sites. The total phenol content of 10 leek accessions ranged from 16 to 21 mg GAE/g dry weight and 16 to 48 mg GAE/g dry weight in the bulbs and leaves respectively.

Sultana *et al*. (2015) investigated the biochemical composition of *Allium tuberosum* Rottler. Ex Spreng gathered from India's western Himalayas. The water extract and ethanolic extracts of *Allium tuberosum* were compared in this experiment. They discovered that total phenol content in water extract of *Allium tuberosum* Rottler Ex Spreng was 157.606 mg/100g DW, whereas total phenol concentration in ethanolic extract was 229.079 mg/100g DW.

At the ICAR-DOGR in Pune, Thangasmy *et al*. (2018) conducted a field experiment on comparison of organic and conventional farming for onion yield and biochemical quality, using the soybean (Kharif)-onion (Rabi) cropping cycle to compare onion output between organic and conventional farming. In comparison to the control treatment, total phenol content rose considerably following the administration of FYM-675 mg GAE/kg (13.4 percent), poultry manure-745 mg GAE/kg (25.2 percent), and vermicompost-723 mg GAE/kg (21.5 percent).

2.4.3 Flavonoids

Stajner and Varga (2003) compared the total flavonoids content in the leaves of wild *Alliums* viz. *Allium atroviolaceum* Bois, *Allium flavum* L., *Allium scorodoprasum* L. *Allium sphaerocephalum* L., *Allium vienale* L. and cultivated *Alliums* viz. *Allium cepa* L., *Allium sativum*., *Allium fistulosum* L., *Allium nutans* L., *Allium schoenoprasum* L., *Allium pskemense* B. Fedtsch, *Allium vienale* L. The leaves of *Allium cepa* L. (496.53 mg/g) had the greatest flavonoids concentration, followed by *Allium scorodoprasum* L. (432.53 mg/g) and *Allium fistulosum* L. (365.87 mg/g). Flavonoids were found in the least level in *Allium flavum* L. (37.87 mg/g).

Marotti and Piccaglia (2002) compared the total flavonoids concentration in twelve cultivars of various coloured onions (white, golden, and red) for fresh bulb. “Darota Density” recorded the highest total flavonoids content (979.1 mg/kg).

Stajner *et al*. (2008) evaluated the total flavonoids content of 17 cultivated and wild species. viz. *Allium sativum* L., *Allium cepa* L., *Allium nutans* L., *Allium fistulosum* L., *Allium pskemense* B.Fedtsch, *Allium schoenoprasum* L., and *Allium vineale* L., and wild growing representatives *Allium atroviolaceum* Boiss, *Allium flavum* L., *Allium roseum* L., *Allium scorodoprasum* L., *Allium sphaerocephalum* L., *Allium subhirsutum* L., *Allium ursinum* L., and *Allium vineale* L. They found the flavonoid concentration to be the highest in *Allium cepa*. In cultivated *A. fistulosum* (Autumn), there was a little decrease in flavonoid content (43.5 percent) as compared to *A. cepa*.

The flavonoid content of *Allium chinense* was determined by Lin *et al*. (2016). *Allium chinense* extracts were subjected to HPLC analysis. At 25.5 minutes and 36.2 minutes, respectively, quercetin and rutin emerged. The concentrations of quercetin and rutin were determined to be 0.10 and 0.07 percent, respectively.

Arfa *et al*. (2015) studied eleven tunician *Allium ampeloprasum* accessions obtained from different locales. The flavonoids content of 10 leek accessions ranged from 1.01 to 5.84 mg CE/g DW in the bulbs and from 4.10 to 4.40 mg CE/g DW in the leaves, respectively. Accessions with the highest amounts of flavonoids were reported as Djeba, Elura, and Samaliettes.

The biochemical makeup of *Allium tuberosum* Rottler. Ex Spreng. was studied by Sultana *et al*. (2015). In this work, water and ethanolic extracts of *Allium tuberosum* were examined. The flavonoids in water extract were 106.310 mg/100g DW, whereas the flavonoids in ethanolic extract were 143.467 mg/100g DW.

Thangasmy *et al*. (2018) conducted a field experiment to evaluate onion yield and biochemical quality between organic and conventional farming, the soybean cropping cycle was used to compare onion production between organic and conventional farming. They discovered that using vermicompost, poultry manure, and farm yard manure considerably raised total flavonoid content by 642 mg/kg (79.3%), 594 mg/kg (65.9%), and 746 mg/kg (108.4%) respectively, when compared to the control condition.

From the water-soluble fraction of the Chinese chive shoot, Oh *et al*. (2021) identified a novel compound, kaempferol-3-O-(6''-feruloyl)-sophoroside (1), as well as one known flavonoid glycoside (2) and six amino acid (3–8) compounds. The isolated compounds were identified using a number of spectroscopic techniques, including 1D and 2D NMR, and their ability to proliferate skeletal muscle cells was tested. Two active chemicals interacted with muscle-related signalling pathways, causing skeletal muscle development and differentiation, according to the findings. Specifically, Compound 1 inhibited smad pathways, which are negative regulators of skeletal muscle development. The principal ingredients of Chinese chive, flavonoids and amino acids, may be employed as dietary supplements to enhance skeletal muscle development and differentiation, according to their findings.

2.4.4 Reducing sugar

Reducing sugars are sugars that have reducing characteristics due to the presence of a possible aldehyde or keto group. Glucose, galactose, lactose, and maltose are examples of reducing sugars. Carbohydrates are essential components of plant storage and structural material. They can be found as free sugars or as polysaccharides (Sadasivam, 1996).

Mahajan *et al*. (2011) examined the biochemical composition of indigenous and foreign onion and garlic cultivars at ICAR-DOGR, Pune. Reducing sugar was investigated in 18 onion and 12 garlic types. They discovered that onions have higher reducing sugar contents (285.7 mg/g fresh wt.) than garlic (7.8 mg/g fresh wt.). They also reported that exotic onions have a higher amount of reducing sugar (559 mg/g fresh weight) than Indian cultivars (451.5 mg/g fresh weight).

Adamczewka *et al*. (2016) investigated garlic chives (*Allium tuberosum* Rottl. EX Spreng) production and biochemical value. In the years 2010-2014, a field experiment was undertaken at Wrocllaw University of Environmental Science. Chive leaves had 11.37 g/kg of reducing sugars, according to the researchers.

The concentration of reducing sugars and total sugar in onion bulbs during storage was examined by Bogevska *et al*. (2016). They discovered that onions stored in traditional methods had a reducing sugar content of (4.8%) while onions stored in cold rooms had a reducing sugar content of (4.6%).

2.4.5 Total sugars

Dyduch and Najda (2000) reported that the total sugar content in young garlic leaves ranged from 19.68 - 22.04%.

At the ICAR-DOGR in Pune, Mahajan *et al*. (2011) examined the biochemical composition of indigenous and foreign onion and garlic cultivars. They discovered that garlic had a higher total sugar content (198.8 mg/g fresh weight) than onion types (78.4 mg/g fresh weight). Indian cultivars had more total sugars (80.2 mg/g fresh weight) than exotic kinds.

The concentration of reducing sugars and total sugars in onion bulbs during storage was compared by Bogevska *et al*. (2016). In conventional onion storage, the average total sugar concentration was 6.0 percent, while the average total sugar content was 5.6% in onions kept in the refrigerator.

2.4.6. TSS (Total soluble solid)

Thangasamy *et al*. (2013) conducted a field experiment at ICAR-DOGR Pune to investigate the influence of sulphur nutrition on pungency and storage life of short-day onion. Sulphur treatment had no effect on TSS, according to the researchers. TSS was detected as 13.63 percent with a sulphur level of 10 kg/ha, 13.42 percent with a sulphur level of 40 kg/ha, and 12.97 percent in the control.

According to Khalid *et al*. (2014), the total soluble solids (TSS) of *Allium tuberosum* and *Allium sativum* were found to differ significantly, in contrast to *Allium sativum* (16.45 percent), the total soluble solid in *Allium tuberosum* was higher (17.95%).

The total soluble solid content of onion cultivars (Dan Zaria, White creole, and Red creole bulb) and garlic was compared by Akinwande *et al*. (2015). Garlic had the highest TSS concentration (19.87°Brix) when compared to onion cultivars (8.83–9.73°Brix).

According to Choudhary *et al*. (2015), TSS concentration ranged from 39.67 ^{o}brix to 43.33 ^{o}brix in Yamuna Safed-3 garlic variety under the impact of various biofertilizers and micronutrients.

Thangasmy *et al*. (2018) conducted a field experiment on onion at ICAR – DOGR, Pune, during 2008-2009 and discovered that combining FYM, PM, VC, and NC (MIX) led to highest TSS content (13.0° Brix), followed by applying NC (12.8° Brix), FYM (12.3° Brix), VC (12.1° Brix), and PM (12.0° Brix). When compared to the control, organic treatments raised TSS concentration by 4.3 – 13.0 percent.

2.4.7 Sulphur

Gambo, *et al*. (2009) investigated the effect of cow-dung, nitrogen, and weed interference on the elemental sulphur content of onion (*Allium cepa* L.). The treatments included three levels of cow dung (0, 15, and 30 t/ha), three levels of nitrogen (0, 50, and 75 kg/ha), and three weeding regimes (weedy check, 4 and 6 weeks after transplanting). Cow-dung, nitrogen, and weed interference all had a significant ($P <0.05$) influence on elemental sulphur concentration in onion bulbs. The highest sulphur concentration was attained with a 15 t/ha cow-dung (0.103 mg/g), 75 kg/ha nitrogen (0.107 mg/g), and 4 weeks after transplanting weeding schedule (0.110 mg/g).

Yabuki *et al*. (2010) used GC–MS and HPLC studies to characterise the composition of sulphur-containing components in Chinese chive (*Allium tuberosum* Rottler). They used 12 varieties of Chinese origin, four variants of Japanese origin, and six commercially available cultivars. On the basis of mass spectral and GC-retention data, five disulphides (allyl methyl, dimethyl, diallyl, allyl 1-(E)-propenyl and methyl 1-(E)-propenyl), two trisulphides (allyl methyl and dimethyl), and two vinyldithiins (2-vinyl-[4H]-1,3- and3-vinyl-[4H]-1,2-) Sulphides with a methyl group predominated over those with an allyl group among the identified sulphur compounds.

Thangasmy *et al*. (2013) conducted a field experiment at ICAR-DOGR, Pune, to study the effect of sulphur feeding on pungency and storage life of short-day onion. They stated that six sulphur levels (0, 7.5, 10, 20, 30, 40, and 50 kg/ha) were sprayed using elemental sulphur (90 percent water soluble powder form), and that sulphur absorption in leaves and bulbs rose significantly as the sulphur levels increased up to 50 kg/ha. The highest sulphur (17.17 ppm) was reported with the application of 50 kg sulphur/ ha.

In *Allium tuberosum* 1, 2, 3, 4, -tetrahydro b-carboline-3-carboxylic acid and tyrosine are reported to be present in the leaves. Sulphur and saponins were reported both in leaves and bulbs. Saponins, tannins, phenols, volatile oil, flavonoids and amino acids were present in the seeds (Devi and Basumatary, 2017).

2.5 Storage parameters

Pelleboer (1984) found that controlled atmosphere (CA) was found to give good results with cauliflower, leek, cabbage and spinach.

Lazan *et al*. (1987) reported that rate of moisture loss was faster under ambient conditions and that sealing of leaves with thin plastic film effectively retarded evaporative water loss in leafy vegetables.

Gomez *et al*. (2003) investigated fenugreek processing and packaging and concluded that the primary processing and packaging technology was suitable for vitamin C, β-carotene, and chlorophyll content, as well as convenience.

Koraddi and Sumangala (2009) investigated the suitability of various packaging materials for storing various vegetables. To extend storage life, the vegetables coriander, fenugreek, tomato, chilli, french bean, cucumber, ladies finger, and carrot were packaged in four different packing materials: polyethylene bags (20 µ), 300-gauge LDPE bags, brown paper bags, and plastic containers. It was observed that no single sort of packing material was adequate for all types of veggies.

The influence of packing material on the shelf-life of minimally processed amaranthus leaves was investigated by Reddy *et al*. (2013). Amaranthus leaves were packaged in polypropylene (100 and 150 gauge), polyethylene (LDPE, HDPE), pouches with or without vents, PET jar, muslin cloth, and brown paper pouches with or without stems. When rajagira leaves with tender stems were packed in polypropylene 150-gauge pouches with vents, shelf life was extended to six days with 84.36 percent moisture retention, 21.01 percent physiological weight loss, and 9.01 percent decaying, while polypropylene 100-gauge pouches had 86.32 percent moisture retention, 1.27 percent physiological weight loss, 16.98 and 14.52 percent yellowing and decaying, respectively.

Kakade *et al*. (2015) investigated several packaging materials for spinach packing and found that the maximum shelf life for spinach was 3 days and 14 days, respectively, when packed in LDPE bags with 5% perforation at ambient and cold storage temperatures.

Narang *et al*. (2016) conducted a study to see if different packing materials could extend the shelf life of fresh fenugreek leaves and bunches. They found that packaging material had significant impact on PLW, visual appearance, total chlorophyll content, and water accumulation. The polypropylene package and bunch form of sample were the best, extending the fenugreek's shelf life to seven days. They also stated that in a polypropylene packaging, fenugreek bunch retained the most chlorophyll, colour, weight loss, aroma, and appearance.

From production to processing and marketing, one of the most extensively used methods for bulk handling of perishables is cold storage. It is a way of preserving perishables in a fresh and healthy form for a longer length of time by managing the temperature (4-15 degrees Celsius) and humidity (80-95 percent) within the storage system. It's vital to keep the temperature and relative humidity at the optimal rate for the shelf life to last as long as it should (Krishnakumar, 2017).

On the basis of physiological loss in weight, sensorial qualities, and microbial count, Garande *et al*. (2019) reported that the shelf life of primary processed fenugreek, coriander, spinach, pokala, and rajgira could be extended to 2, 3 and 8 days, 2, 3 and 6 days, 2, 4 and 8 days, 2, 4 and 6 days, and 2, 4 and 8 days at room temperature, zero energy cool chamber, and refrigerated storage, respectively.

Chinese chives have very delicate leaves that quickly lose their freshness. They cannot be stored for more than 2 to 3 days, and even then, they must be kept at 0 to 2°C to maintain quality. During these few days of cold storage, the carotene concentration dropped to less than half of its initial value as reported by Saito, S., 2020.

Mishra *et al*. 2020 reported that ZECC can be used as a storage structure for vegetables such as pointed gourd and okra. Vitamin C significantly increased on the fifth day of storage compared to the first day for all types of storage. The PLW was higher in freeze storage condition compared to that of ZECC condition.

2.6 Effect of growing condition

Microclimate information is critical for improved crop management. Photosynthesis requires an adequate quantity of light; yet, crops that receive excessive light may be stressed and lower their output by shutting their stomata. Sunburn can occur on leaves exposed to high amounts of direct sunlight, reducing the marketable yield significantly. More shade, on the other hand, may result in lower productivity and quality as a result of less light (Hemming, 2009).

Sunlight is the primary source of energy for photosynthesis and transpiration in plants, and it is also important in determining tissue temperature, which has implications for metabolic process speeds and balance (Jones, 1992).

Brand (1997) examined into how shading affected the growth, foliar chlorophyll concentration, and foliar colour of container-grown *Kalmia latifolia* cultivars during nursery production. For two years, five cultivars of *Kalmia latifolia* were planted in full sunshine, 40% shade, and 60% shade. Shade increased foliar colour and chlorophyll concentration by lowering brightness, lowering chroma, and shifting the hue angle from yellow-green to darker green, according to the findings. For the first year, growth characteristics (plant size, number of branches, leaf area, leaf dry mass, and stem dry mass) did not differ significantly in response to light treatment, but for the second year, growth characteristics (plant size, number of branches, leaf area, leaf dry mass, and stem dry mass) decreased directly with increasing shade.

Marenco *et al*. (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth. By increasing shade level, leaves and roots were reduced. Leaf area was greater in plants grown at 50% shade level than n those that were grown under 0 or 70% shade level but relative growth rate was better in shaded than in unshaded plants. Leaf thickness was lower in plants cultivated at high shade levels than in open conditions and also observed reduction in dry matter accumulation in leaves, roots and culms by increasing shade levels.

Sladek *et al*. (2009) conducted an experiment to assess the relative differences in growth to three light intensities (0 percent, 50 percent, and 90 percent shade) among six Zoysia grass genotypes under artificial shade conditions, concluding that significant differences in shade tolerance exist between Zoysia grass genotypes. Turf grass quality dropped as shadow level increased in all genotypes studied, and none of the cultivars received more than 6 ratings for satisfactory turf quality at 12 weeks after planting when growing in 90% shade.

Stanton *et al*. (2010) studied two shrubs, *Spiraea alba* and *Spiraea tomentosa*, in six distinct light conditions: full sun, morning full sun, afternoon full sun, and 40%, 60%, and 80% shade. Full daylight and 40 percent shade levels produced the most growth, canopy density, and blooming, whereas 80 percent shade produced the least. Individual leaf area and specific leaf area increased in both species in response to shade. In *S. tomentosa*, relative leaf greenness reduced as shade levels increased. Finally, they stated that while these species may live in deep shade, they are best suited to full sun or moderate shade in the landscape due to their growth and development.

Allium tuberosum

Chinese chive is seeds have been reputedly used as a traditional Chinese medicine for treating both impotence and nocturnal emissions (Jiangsu New Medicinal College, 1979).

Guohua *et al*. (2009) investigated the aphrodisiac efficacy of *Allium tuberosum* seeds n-BuOH extract in male rats. For 40 days, the extract (500 mg/kg body weight/day) and L-dopa (100 mg/kg body weight/day) were given orally by gavages. The parameters observed before and throughout the sexual behaviour research at day 0, 10, 20, 30, and 40 were mount latency (ML), intromission latency (IL), ejaculation latency (EL), mounting frequency (MF), intromission frequency (IF), ejaculation frequency (EF), and postejaculatory interval (PEI). The n-BuOH extract significantly reduced ML, IL, EL, and PEI ($p < 0.05$), according to the data. The extract also increased MF, IF, and EF significantly ($p < 0.05$). Both sexually active and inactive male rats showed these effects. These findings show that the n-BuOH extract of *Allium tuberosum* seeds has aphrodisiac properties in an experiment conducted.

Liu *et al*. (2015) conducted an experiment to test the larvicidal effect of the essential oil and compounds of *Allium tuberosum* Rottler ex Sprengle roots against larval mosquitoes (*Aedes albopictus* Skuse). Hydrodistillation was used to extract the essential oil of *A. tuberosum*, which was then evaluated using gas chromatography and gas chromatography–mass spectrometry. Sulfur-containing chemicals, such as allyl methyl trisulfide (35.19 percent), diallyl disulfide (28.31 percent), diallyl trisulfide (20.91 percent), and dimethyl trisulfide (20.91 percent), were determined to constitute the primary components. The essential oil of *A. tuberosum* had larvicidal action against *Aedes albopictus* fourth-instar larvae, with an LC50 of 18 lg/ml. Diallyl trisulfide (LC50 ¼ 4 lg/ml) and diallyl disulfide

(LC50 ¼ 6 lg/ml) had greater larvicidal action against *Aedes albopictus* fourth-instar larvae than allyl methyl trisulfide (LC50 ¼ 27 lg/ml) and dimethyl trisulfide (LC50 ¼ 35 lg/ml). The findings suggested that *A. tuberosum* essential oil and its primary components had high potential as a natural larvicide source.

Huang *et al*. (2016) examined that the chinese leek (*Allium tuberosum* Rottler ex Sprengel) is resistant to root knot nematodes, has great nematicidal activity against *Meloidogyne incognita*, and can significantly lower the prevalence of nematode infestation. The gall indexes of cucumber and tomato plants intercropped with Chinese leek were lowered by 70.2 and 41.1 percent, respectively. The gall indexes of Chinese leek extract-treated tomato and cucumber plants were lowered by 88.9% and 75.9%, respectively, in the pot experiment. The death rate of an root knot nematode (*Meloidogyne incognita* J2) treated with Chinese leek extract was substantially greater than the control in an in vitro experiment.

Allium chinense

Plant bulbs of Jiaotou (*Allium chinense*) are claimed to cure mental tension, cardiac problems, and cancers in Chinese traditional medicine, and are also used in a variety of medicinal formulations (Cooper & Johnson, 1984). This plant is used to make the Chinese crude medication 'Xiebai,' which is used to cure stenocardia, heart asthma, and stagnant blood (Davies, 1992).

Allium chinense is utilised as an anti-tumor agent in Chinese traditional medicine; one of the active ingredients found in the ethylacetate soluble fraction was an acid amide that has a notable inhibitory impact on platelet aggregation in humans (Okuyama *et al*., 1986). According to Toyama and Wakamiya (1990), *Allium chinense* has positive benefits in the treatment of bronchitis, pleurisy, angina pectoris, chest discomfort, stuffiness feeling, tenesmus, and diarrhoea.

In high-fat-diet Wistar rats, ethanol extracts from *Allium chinense* showed significant antioxidant activity, and its high-dose essential-oil extract significantly reduced serum and hepatic total cholesterol, triglyceride, and low-density lipoprotein levels while increasing serum high-density lipoprotein levels compared to those seen after treatment with probucol (Lin *et al*., 2016).

Antibacterial activity was found in *A. chinense* leaf and bulb extracts against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. When it came to *Aspergillus niger*, leaf extract was more effective than bulb extract. The increased concentration of total saponin and terpenes could explain their enhanced action (Rhetso *et al*., 2020).

Materials and methods

3. MATERIALS AND METHODS

The current study, titled **Performance evaluation of underutilized edible *Alliums***, was conducted from October 2021 to May 2021 at the Department of Plantation Crops and Spices, College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur district, Kerala. The experimental plot is located at 100 31'N latitude and 76013' E longitude in central Kerala, at an elevation of 22.25m above mean sea level. This chapter goes over the specifics of the materials used and the procedures followed during the investigation.

3.1 Experimental material

Two species of *Allium* viz. *Allium tuberosum* and *Allium chinense* were gathered from North East India and authenticated at NBPGR (National Bureau of Plant Genetic Resources). The plants were grown in two growing conditions *viz.* rain shelter and open field condition in growbags.

3.2 Design and layout of the experiment

A completely randomised design was utilised in the study, with four treatment combinations and four replications of the two species, *A. tuberosum* and *A. chinense*, which were grown in growbags under rain shelter and open field conditions. The plants were cultivated between October 2020 and May 2021. Details of treatment combinations are given below.

Rain shelter		**Open condition**	
A.t (RS)	**A.c (RS)**	**A.t (OC)**	**A.c (OC)**
R1 -10 plants	R1 -10 plants	R1 -10 plants	R1 -10 plants
R2 -10 plants	R2 -10 plants	R2 -10 plants	R2 -10 plants
R3 -10 plants	R3 -10 plants	R3 -10 plants	R3 -10 plants
R4 -10 plants	R4 -10 plants	R4 -10 plants	R4 -10 plants

*RS – Rain shelter *OC – Open field condition

3.2.1 Pot culture experiment

Tillers were used as planting material. They were planted in grow bags (25 x 40cm) filled with mixture of soil, sand, FYM in equal proportions. Immediately after planting a light irrigation was given and mulched with straw. Irrigation was given on alternate days.

The number of grow bags in each of the species is given below:

A.t (RS) : *Allium tuberosum* in rain shelter : 40 grow bags

A.t (OC) : *Allium tuberosum* in open condition: 40 grow bags

A.c (RS) : *Allium chinense* in rain shelter : 40 grow bags

A.c (RS) : *Allium chinense* in open condition : 40 grow bags

For each replication five plants were tagged for recording observations.

3.3 Meteorological data

Appendix 1 contains weather data from the experimental site obtained from the Department of Agricultural Meteorology, College of Agriculture, Vellanikkara.

3.4 Intercultural operations

During the cropping time, necessary intercultural activities were carried out to ensure the plants' healthy growth and development. Once in every two days, the plants were irrigated. Other intercultural operations, including weeding and plant protection, were implemented as needed.

3.5 Fertilizer management

At monthly intervals, 19:19:19 fertiliser was applied as foliage spray.

Open condition

Rain shelter

Plate 1: Experimental plot of *Allium* species grown under open condition and rain shelter

Allium tuberosum

Allium chinense

Plate 2: Propagules (tillers) of *Allium tuberosum* and *Allium chinense*

3.6 Observation procedure

To record the data of morphological parameters (No. of leaves, No. of tillers, No. of leaves per tiller, plant height, leaf length, leaf breadth and leaf area), five plants were chosen at random from each replication and the mean value was acquired at monthly intervals. All attributes were observed, and the process was repeated for each entry. Fresh leaf samples were taken for examination of physiological and biochemical parameters such as total chlorophyll, chlorophyll ‘a’, chlorophyll ‘b’, total carotenoides, dry matter, moisture content, relative water content, TSS, ascorbic acid, phenol, flavonoids, total sugar, reducing sugar, non-reducing sugar, and sulphur content. The procedure for keeping track of observations is outlined below.

3.6.1 Morphological parameters

3.6.1.1 Number of leaves

In each replication, five plants were chosen at random and tagged. The mean value of the number of leaves per plant was calculated by counting the total number of leaves from each of the tagged plants.

3.6.1.2 Number of tillers

The mean value of the number of tillers per plant was calculated by counting the total number of tillers from each of the tagged plants.

3.6.1.3 Plant height (cm)

In each replication, five plants were chosen at random and tagged. With the use of a measuring scale, the plant height was measured from the ground level to the tip of the tallest leaf at maturity and stated in centimetres.

3.6.1.4 Leaf length (cm)

Top fourth leaf was used for measuring leaf length. Leaf length, measured with a measuring scale from the pseudo stem to the tip of the leaf and represented in centimetres.

3.6.1.5 Leaf breadth (cm)

The leaves that were used to measure length were also used to measure the breadth of the leaves. Using a measuring scale, the width in cm was measured at the broadest section of the leaves.

3.6.1.6 Leaf area (cm^2)

The area of a leaf is measured using a leaf area metre and is expressed in cm square.

3.6.1.7 Leaf yield parameters

Harvesting was done three times; first harvest at 90 days after planting, second harvest was done at 90 days after first harvest and third harvesting was done at 90 days after second harvest. Three cuttings were made at three months interval and fresh weight of the leaves was measured and expressed in grams.

3.6.2 Physiological parameters:

3.6.2.1 Estimation of chlorophyll content

Principle:

Chlorophyll is extracted in 80% acetone and the absorption at 663 nm and 645 nm are read in a spectrophotometer. Using the absorption coefficients, the amount of chlorophyll is calculated.

Materials:

Dilute analytical grade acetone to 80% acetone (prechilled).

Procedure:

Weighed one gram of a finely chopped and thoroughly mixed representative sample of leaf tissue in a clean mortar. With the addition of 20ml of 80% acetone, ground the tissue to a fine pulp. Centrifuged for 5 minutes at 5,000 rpm, then transferred the supernatant to a 100 ml volumetric flask. Centrifuged the supernatant and transferred it to the same volumetric flask after grinding the residue with 20 ml of 80% acetone. Repeat this step until the residue was colourless. Washed the mortar and pestle thoroughly with acetone and collect the clear washings in a volumetric flask. Filled the remaining 100 ml with 80 percent acetone. At 645, 663, and 652 nm, compared the absorbance of the solution to that of the solvent (80% acetone) blank.

Calculation:

Calculated the amount of chlorophyll present in the extract mg chlorophyll per g tissue using the following equations:

$$\text{Mg chlorophyll } a\text{/g tissue} = 12.7\ (A_{663}) - 2.69\ (A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Mg chlorophyll } b\text{/g tissue} = 22.9\ (A_{645}) - 4.68\ (A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{Mg total chlorophyll/ g tissue} = 20.2\ (A_{645}) + 8.02\ (A_{663}) \times \frac{V}{1000 \times W}$$

Where,

A = absorbance at specific wavelengths

V = Final volume of chlorophyll extract in 80% acetone

W = fresh weight of tissue extracted

3.6.2.2 Estimation of total carotenoids

Procedure:

Weighed leaf sample (5g). Using acetone, ground in a mortar and pestle. Filter into a conical flask through a cotton swab. Extraction and filtration was continued until the residue was colourless. Filled a separating funnel halfway with the filtrate. Added 10 to 15 mL petroleum ether to the mixture. Repeated the process with the pigments in the petroleum ether phase until no more colour was removed. Sodium sulphate was used to filter the water. Made up to a predetermined volume. Using petroleum ether as a blank, measured at 452nm.

Calculation:

$$\text{Mg of carotene per 100g} = \frac{3.857 \text{ x OD X Volume}}{\text{Weight}} \text{ X } 100$$

3.6.2.3 Dry matter content (%)

Each replication's leaves sample was placed in a paper bag with perforations on both sides. The bags were maintained in a 60°C hot air oven until they reached their constant weight. To calculate the dry matter content of each sample, the dry weight was divided by the fresh weight of the leaves and then multiplied by a hundred.

$$\text{DM (\%)} = \frac{\text{Dry weight of plant}}{\text{Fresh weight of plant}} \text{ X } 100$$

3.6.2.4 Relative water content (%)

The relative water content (RWC) was determined using the Tambussi *et al.* (2005). technique. To minimise moisture loss, the fully inflated top most leaf was removed from the plant using the normal technique and promptly switched to an ice bucket before being carried to the laboratory. To capture the fresh weight, the samples were weighed rapidly. The samples were hydrated to full turgidity by floating for 6 hours at room temperature in de-ionized water in a closed petri dish. After removing the leaf from the water for 6 hours, the surface was wiped to remove surface water. To achieve turgid weight, the leaf was reweighted. The samples were dried for 25 hours in an 80°C hot air oven. After appropriate drying, the dry weight of the samples was weighed (till the weight became constant). The following calculation was used to calculate the relative water content (percent):

RWC (%) = [(Fresh weight – Dry weight) / (Turgid weight – Dry weight)] x 100

3.6.2.5 TSS (%)

The total soluble solids content of *Allium* leaf extract was directly measured by the Zeiess Hand Refractometer (0-30) and value obtained was corrected at 200°C. (A.O.A.C, 1984)

3.6.3 Biochemical parameters:

All of the glassware utilised for analysis in biochemical research was borosilicate glassware. A cleaning solution, such as a 1 percent HCl solution, was used to clean these glass wares. For further investigation, the cleaning solution was entirely removed by washing well with tap water and then rinsing with distilled water.

3.6.3.1 Estimation of ascorbic acid

Principle:

The 2, 6 dichlorophenol indophenols dye is reduced to a colourless leuco base by ascorbic acid. Although the dye is a blue-coloured molecule, the ascorbic acid is oxidised to dehydroascorbic acid, resulting in a pink colour. The titrating media is metaphosphoric acid.

Reagent:

1. Metaphosphoric acid at a concentration of 3%.

2. **Dye solution:** In a tiny amount of distilled water, weighed 42 mg sodium bicarbonate. Made up to 200ml with distilled water after dissolving 52 mg 2, 6- dichloro phenol indophenol in it.
3. **Standard stock solution:** In a standard flask, dissolved 100 mg ascorbic acid in 100 ml of 3% metaphosphoric acid solution (1 mg/ ml).
4. **Working standard:** Diluted 10 ml of the stock solution with 3 percent metaphosphoric acid to make it 100 ml. The working standard has a concentration of 100 µg/ml.

Procedure:

By titrating newly extracted juice against 2, 6- dichlorophenol indophenols dye, the ascorbic acid concentration of the leaf extract was measured (A.O.A.C., 2001). In a volumetric flask, one gram of leaf sample was crushed with a 3% metaphosphoric acid solution and the volume was made up to 100ml with distilled water. After 10 minutes, a 5ml aliquot of the filtrate was collected, 10ml 3% metaphosphoric acid was added, and the solution was titrated against a standard 2, 6- dichlorophenol indophenol dye solution. The arrival of pink colour, which lasted for 15 seconds, signalled the conclusion point. Ascorbic acid concentration was measured in milligram per gram of fresh weight.

Calculation:

$$\text{Amount of ascorbic acid (mg/100g)} = \frac{\text{Dye factor x } V_2 \text{ (ml) x 100 ml x 100}}{V_1 \text{ (ml) x 5 (ml) x weight of sample (g)}}$$

3.6.3. 2 Estimation of phenol content

Total phenols was measured by the method given by Bray *et al.*, 1954.

Principle:

In the Folin-ciocalteau reagent in alkaline medium, phenols react with phosphomolybdic acid to generate a blue-coloured complex (molybdenum blue).

Reagents:

1. 80% Ethanol: 80ml Ethanol was dissolved in 100ml distilled water.
2. 20% Sodium carbonate (Na_2CO_3: 20g Na_2CO_3 was dissolved in 100ml distilled water.
3. Folin-ciocalteau's reagent
4. Standard (100 mg Catechol in 100 ml water)
5. Dilute 10 times for a working standard

Procedure:

One mg leaf sample was weighed and homogenated with 10ml 80% ethanol. It was centrifuged at 10000 rpm for 10 minutes. Supernatant solution was collected and 10ml of 80% ethanol was added again to the residue, centrifuged it. Supernatant 2 was mixed with supernatant 1 and used for estimation. Residue was discarded. 200µl of extract was taken in test tube and added 1ml FCR and incubated it for 5 minutes at room temperature. Then, 800µl of 20% Na_2CO_3 was added and incubated for 2 hours in dark. The absorbance was recorded at 765nm using a spectrophotometer. A standard curve was constructed based on a range of catechol concentrations (0.1 mg/ml to 0.5 mg/ml). Results were expressed as mg/g Catechol.

3.6.3.3 Estimation of flavonoids

With minor changes, the total flavonoids content was calculated as proposed by Olivera (2008).

Principle:

In addition to aluminium chloride, the C-4 keto group and either the C-3 or C-5 hydroxyl group of flavones and flavonols form acid stable complexes. The ortho-dihydroxyl groups in flavonoids' A- or B-rings also form acid labile complexes with aluminium chloride. Quercetin is used as a reference solution for constructing the calibration curve. A standard calibration curve was created using various concentrations of standard quercetin solution.

Reagents:

1. $NaNO_2$ with a concentration of 1.5% (0.5 g $NaNO_2$ dissolved in 10 mL distilled water)
2. $AlCl_3$ at a concentration of 10% (1 g of $AlCl_3$ in 10 mL of distilled water)
3. NaOH (1M) [2 g sodium hydroxide (NaOH) diluted in 50 mL distilled water]
4. Stock solution of quercetin (Quercetin 0.250 g dissolved in 50 mL Ethanol)

Procedure:

80 percent methanol was used to extract one gram of the leaf sample. The supernatant solution was recovered after centrifuging the extract for 10 minutes at 10,000 rpm. One millilitre of extract was combined well with four millilitres of distilled water. To the aforementioned mixture, 0.3 ml of 5% $NaNO_2$ was added and incubated for 5 minutes. In addition, 0.3ml of 10% $AlCl_3$ was added and the system was left on standby for 6 minutes. To the aforementioned mixture, two ml of 1M NaOH was added, followed by 2.4 ml of distilled water. The aforementioned ingredients were well combined and incubated for 20 minutes at 18°C in the dark. A Spectrophotometer was used to measure the absorbance at 510 nm. A standard curve was created using a variety of quercetin concentrations.

3.6.3.4 Estimation of total sugars

Total sugar was estimated by Anthrone method (Sadasivam and Manickam, 1996)

Principle: Using dilute hydrolysis acid, carbohydrates are first hydrolyzed into simple sugar. Glucose is dehydrated to hydroxymethyl furfural in a hot acidic media. Anthrone, a green-colored substance with a 630nm absorption maximum, is formed by this chemical.

Reagents:

1. HCl (2.5 N)
2. **Anthrone reagent:** 200 mg anthrone dissolved in 100 ml ice cold 95 percent H_2SO_4 freshly produced before use.
3. **Glucose Solution (Standard)**

   Stock standard: 100 milligrams glucose dissolved in 100 ml water**.**

   Working standard: Diluted 10 ml of stock solution to 100 ml with distilled water.

Procedure:

100 mg of *Allium* leaf samples were weighed and hydrolysed to simple sugar in a boiling water bath with 5ml of 2.5N HCl for three hours. After cooling to ambient temperature, the sample was neutralised with solid sodium carbonate and centrifuged to get a clear solution. By adding distilled water to 0.5ml of an aliquot of material, the final volume was increased to 1ml. After that, 4 ml of anthrone reagent was placed in a tube and heated in a boiling water bath for 8 minutes. The green colour was generated after cooling, and it was measured at 630nm. Finally, using the usual graph, the carbohydrate content was calculated.

3.6.3.5 Estimation of reducing sugars

Reducing sugar content was estimated by Nelson-Somogyi method (Sadasivam and Manickam, 1996).

Principle: The reducing sugars change the copper from the cupric to the cuprous state when heated with alkaline copper tartarate, resulting in the production of cuprous oxide. The reduction of molybdic acid to molybdenum blue occurs when cuprous oxide is treated with arsenomolybdic acid. In a colorimeter at 620 nm, the blue colour is compared to a set of standards.

Reagents:

Alkaline copper tartarate-

A) In 80 mL water, dissolved 2.5 g anhydrous sodium carbonate, 2 g sodium bicarbonate, 2 g potassium sodium tartarate, and 20 g anhydrous sodium sulphate and formed a volume of up to 100ml.

B) In a little amount of distilled water, dissolved 15g copper sulphate. One drop of sulphuric acid was added, and the mixture was adjusted to 100 ml. Mixed 4 ml of B Reagent with 96 ml of Reagent A before using.

Arsenomolybdate Reagent-

2.5 g ammonium molybdate dissolved in 45 ml water 2.5 ml sulphuric acid was added and well mixed. Then, in 25ml water, dissolved 0.3g disodium hydrogen arsenate. Incubated for 24 hours at 37°C after thoroughly mixing.

Procedure:

The Nelson-Somogyi technique was used to calculate the reducing sugars. Weighed 100 mg of *Allium* leaves and ground them with 5ml of 80 percent hot ethanol by retaining the supernatant solution in an 80°C water bath, it was evaporated. To dissolve the sugars, 10 ml of water was poured to the tube. After adding alkaline copper tartarate, the extract was placed in test tubes and maintained in boiling water for 10 minutes. The arsenomolybdic acid reagent was then added to each tube at a volume of 1 ml. By adding distilled water, the final amount was increased to 10 ml. After 10 minutes, a spectrophotometer was used to measure the absorbance of the blue-colored samples at 620 nm. The reducing sugars were estimated using the standard graph.

3.6.3.6 Estimation of non-reducing sugar

Non reducing are estimated by simply subtracting the amount of reducing sugars from the total sugar content present in the sample.

3.6.3.7 Estimation of plant sulphur

Reagents:

1. **0.15% $CaCl_2$ solution:** Dissolve 1.5gram calcium chloride dihydrate ($CaCl_2$. $2H_2O$) in 500 ml distilled water to made up the volume to 1 litre.
2. **Gum acacia-acetic acid solution:** 0.25g chemically pure gum acacia dissolved in hot water, filtered using Whatman No. 42 filter paper. Allow the filtrate to cool before diluting to 100 ml.
3. **Barium chloride ($BaCl_2$):** Analytical grade $BaCl_2$ should be ground to pass through a mesh sieve.
4. **Concentrated standard sulphate solution (100 mg S ml^{-1}):** In distilled water, dissolve 0.5434 g oven dried AR potassium sulphate (K_2SO_4) and made up to 1 litre.
5. **Working standard sulphate solution (10µg S ml^{-1}):** Using distilled water, dilute 5 mL of the concentrated standard sulphate solution to 1 litre.

Procedure:

Extraction (Tabatabai, 1982)

Shake 10 g of air-dried leaf samples in a 250 ml conical flask for 30 minutes with 10 ml of 0.15 percent $CaCl_2$ solution. Filter the extract using Whatman No. 42 filter paper and used a turbidimetric technique to calculate the sulphate concentration.

Preparation of standard curve

In separate 25ml volumetric flasks, pipette out 0, 0.25, 0.5, 1.0, 2.5, and 5 ml of standard sulphate solutions, then add 10 ml of extracting solution (0.15 percent $CaCl_2$). When a batch of samples is analysed, the standards must be prepared a fresh from each time. Swirl 1g of $BaCl_2$ crystals into each flask to dissolve them. Add 1 ml of 0.25 percent gum acacia solution, top up with distilled water, and shake well. Read the absorbance at 440 nm using a spectrophotometer within 5-30 minutes of the turbidity developing. Draw a standard curve with the Y axis representing absorbance and the X axis representing concentration.

Turbidimetric estimation of Sulphur (Massoumi and Cornfield, 1963)

Pipette 10 ml of the leaf extract into a volumetric flask with a 25 ml capacity. Swirl in 1 gramme of $BaCl_2$ crystals to dissolve them. Add 1 ml of 0.25 percent gum acacia solution, make up with distilled water, and shake well. Read the absorbance at 440 nm using a spectrophotometer within 5-30 minutes of the turbidity developing.

Calculation:

$$\text{Sulphur (\%)} = \frac{\text{Concentration x volume of extract x total volume}}{\text{Weight of sample x aliquot taken x 1000000}} \text{ X 100}$$

3.6.5 Storage experiment

Experimental details

The harvested leaves were stored at three different storage temperature i.e., refrigeration storage (5-7℃), cold storage (12-13℃) and ambient conditions (30-35℃).

Statistical design	: CRD
Packaging material	: 200-gauge LDPE, 200-gauge LDPE with perforation, Brown paper bag, tissue paper wrapping.
Replications	3
Sample size	: 10 grams

The following are the details of the treatment:

Storage temperature

1) T_1: Refrigeration: 5-7℃
2) T_2: Cold storage: 12-13℃
3) T_3: Ambient conditions: 30-35℃

Packaging materials

1) P_1: 200-gauge LDPE
2) P_2: 200-gauge LDPE with perforation
3) P_3: Brown paper bag
4) P_4: Tissue paper wrapping

There was a total of twelve treatment combinations. The details of which are shown in the table below.

Sl. No.	Treatment symbol	Treatment combinations
1	T_1P_1	Refrigeration + 200-gauge LDPE
2	T_1P_2	Refrigeration + 200-gauge LDPE with perforation
3	T_1P_3	Refrigeration + Brown paper bag
4	T_1P_4	Refrigeration + Tissue paper wrapping
5	T_2P_1	Cold storage + 200-gauge LDPE
6	T_2P_2	Cold storage + 200-gauge LDPE with perforation
7	T_2P_3	Cold storage + Brown paper bag
8	T_2P_4	Cold storage + Tissue paper wrapping
9	T_3P_1	Ambient condition + 200-gauge LDPE
10	T_3P_2	Ambient condition + 200-gauge LDPE with perforation
11	T_3P_3	Ambient condition + Brown paper bag
12	T_3P_4	Ambient condition + Tissue paper wrapping

3.6.5.1 Effects of storage methods and packaging materials on physiological loss of weight (%) of *Allium* leaves

The substantial change in physiological weight loss of packed leaves during storage was assessed on a percentage basis at the beginning and end of treatment based on the fresh produce weight. In all samplings, the fresh weight was determined using an electronic scale with a precision of 0.01 g, and the % reduction in weight over the original weight was computed using the technique outlined by Ranganna (1986).

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

Weighing was carried at alternate day interval on individual packed samples at controlled air conditions to avoid moisture condensation on the packages. Minimum 10-15% PLW was taken into account as an acceptable parameter for economic shelf life of leafy vegetables.

3.6.5.2 Effects of storage methods and packaging materials on Organoleptic quality of *Allium* leaves

Overall acceptability

Overall acceptability score for leaves was determined on the basis of colour, appearance, texture, taste, odour by a panel of evaluators based on rating with 9-point Hedonic scale given by Amerine *et al*. (1965).

3.7 4 Statistical analysis

The data was presented as an average of replicate values and submitted to the statistical analysis described below.

3.7.4.1 Analysis of variance

The analysis of variance was performed independently for each character using Panse and Sukhatme (1954). The following skeleton was used to assess the significance of variations between treatments. The computed value of "F" was compared to the tabular value of "F" to determine the significance of therapy. All of the tests have a significance level of 0.05.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F value Calculated Tabulated
Replication	(r-1)	RSS		$\frac{M1}{M2}$
Treatment	(t-1)	TrSS	M1	
Error	(r-1) (t-1)	ErSS	M2	

Level of significance is at 5%

Where,

r = No. of replications

t = No. of treatments

RSS = Replication sum of squares

TrSS = Treatment sum of squares

ErSS = Error sum of squares

M1 = Mean sum of squares due to treatment

M2 = Mean sum of squares due to error

a. Critical difference

CD = SE (d) X t value at 5% at error degree of freedom

Where,

SE (d) = Standard error of difference between two treatment means

b. Standard error of difference between two treatment means

$$SE\ (d) = \sqrt{\frac{2EMS}{r}}$$

Where,

EMS = Error mean square

r = Number of replications

C. Coefficient of variation (CV) %

Coefficient of variation is standard deviation expressed as percentage of mean.

$$CV\ \% = \frac{SD}{\bar{X}} \times 100$$

Where,

SD = Standard deviation and $\bar{X}$ = Mean of character

Results and discussion

4. RESULTS AND DISCUSSION

The present study tested the performance of two underutilised *Allium* species (*A. tuberosum* and *A. chinense*) under two different growing conditions (rain shelter and open field). Morphological, physiological, biochemical, and storage studies were conducted and the data generated were then statistically analysed. Results of the study are presented and discussed under the following sub heads.

4.1 Morphological characteristics

4.2 Yield characteristics

4.3 Physiological characteristics

4.4 Biochemical characteristics

4.5 Storage study

The following paragraphs present the outcome of each of the aforementioned aspects.

4.1 Analysis of variance

Table 4.1 shows the results of the analysis of variance for all of the characteristics studied. The mean sum of squares of treatments was significant for all of the characteristics studied in the analysis of variance. This indicates that there is variation in leaf yield and its component characteristics between species, as well as between the growing environments. Significant mean sum of squares due to leaf yield and attributing characteristics indicated that the material tested for improvement of various qualities has a lot of variability. These results are similar to those of Jafari *et al.* (2017) who worked on the accessions of *A. akaka* and *A. elburzense* and found that the analysed *Allium* accessions under study growing naturally in Iran exhibited significant amount of variability.

4.2 Mean performance

The observation on five plants from each treatment of four replications for leaf yield and its component characters were used for calculating the mean performance. The observations were first averaged for five plants taken randomly for each replication in each treatment and were later averaged. The mean performance of each treatment combinations are presented character wise in the table 4.2.1 and described below.

Table 4.1: Analysis of variance for morphological characteristics

Sl. No.	**Characters**	**Mean squares**	
		Treatment	**Error**
	Df = 6	**Df = 6**	**Df = 21**
1.	Number of leaves per plant	842.42	45.70
2.	Number of tillers	28.85	2.51
3.	Number of leaves per tiller	9.55	1.42
4.	Plant height	240.60	103.17
5.	Leaf length	156.27	64.529
6.	Leaf width	0.05	0.01
7.	Leaf area	120.69	20.04

Allium tuberosum

Allium chinense

Plate 3: *Allium tuberosum* and *A. chinense* grown under open condition at 60 DAP

Allium tuberosum

Allium chinense

Plate 4: *Allium tuberosum* and *Allium chinense* grown under rain shelter at 60 DAP

4.2.1 Morphological characteristics

Table 4.2.1: Number of leaves per plant in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
A.t (RS)	3.78	5.98	10.95	15.42	23.96	34.52	40.74
A.t (OC)	3.80	7.00	13.43	22.56	31.67	43.28	52.32
A.c (RS)	2.55	3.24	4.37	7.76	14.05	21.39	26.80
A.c (OC)	3.03	6.04	14.09	16.93	27.94	35.97	46.42
C.D (5%)	**0.36**	**0.54**	**0.59**	**1.10**	**1.61**	**1.24**	**1.62**
S.E (d)	**0.16**	**0.24**	**0.27**	**0.50**	**0.73**	**0.56**	**0.74**
C.V (5%)	**6.94**	**6.21**	**3.51**	**4.53**	**4.23**	**2.35**	**2.51**

For both the species, observations were made at monthly intervals for seven months. Table 4.2.1 and fig- 4.1 displays information on the number of leaves per plant in *Allium* species grown under different growing conditions. *Allium* species exhibited a wide range of leaf numbers. At 210 days after planting, the number of leaves ranged from 26.79 to 52.31.

In both the growth circumstances evaluated during the course of the experimentation, the number of leaves in *Allium tuberosum* followed an upward trend throughout the period of crop development, with the lowest number on 30 DAP and the highest number on the last data of sampling, 210 DAP. In terms of the number of leaves per plant, the open condition proved to be the best, with more leaves per plant on 30 DAP (3.8) to 210 DAP (52.31). Plants that were cultivated under a rain shelter had less leaves on the respective dates (3.77 at 30 DAP and 40.73 at 210 DAP).

In both the growth circumstances evaluated during the course of the experimentation, the number of leaves in *Allium chinense* followed an upward trend throughout the period of crop development, with the lowest number on 30 DAP and the highest number on the last data of sampling, 210 DAP. In terms of the number of leaves per plant, the open condition proved to be the best, with more leaves per plant on 30 DAP (3.02) to 210 DAP (46.41). Plants that were cultivated under rain shelter had less leaves on the respective dates (2.55 at 30 DAP and 3.02 at 210 DAP).

Number of leaves per plant determines the yield by determining the relative growth rate and net assimilation rate. Based on our findings we may conclude that both species produced more number of leaves in open condition and less number of leaves in rain shelter. When comparing the two species, *A. tuberosum* had more number of leaves between 30 and 210 DAP in both the growing conditions than *A. chinense*. Significant difference was noticed for this character in both the species under both growing conditions and the variation between the growing condition was less in *Allium tuberosum* than in *Allium chinenese*.

Different *Allium* species

The variability for number of leaves was also observed by Nurzynska-Wierdak (1997) in garlic ecotypes; Kohli and Prabhal (2000) in garlic clones; Jogdande *et al*. (2004) in garlic genotypes; Sengupta *et al*. (2007) in garlic varieties and Panse *et al*. (2013) in garlic germplasms.

Different growing conditions

Marenco and Reis (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth and he stated that, by increasing shade level, leaves and roots were reduced.

Allium tuberosum

Allium chinense

Plate 5: *Allium tuberosum* and *A. chinense* grown under open condition at 150 DAP

Allium tuberosum

Allium chinense

Plate 6: *A. tuberosum* and *A. chinense* grown under rain shelter at 150 DAP

Table 4.2.2: Number of tillers per plant in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
A.t (RS)	0	0.75	1.30	2.14	3.65	5.60	6.00
A.t (OC)	0	0.81	1.80	3.90	6.85	8.15	8.60
A.c (RS)	0	0.17	0.33	0.92	1.41	3.66	4.00
A.c (OC)	0	0.58	2.58	4.30	7.21	8.50	10.75
C.D (5%)	**-**	**0.29**	**0.35**	**0.39**	**0.33**	**0.75**	**0.57**
S.E (d)	**-**	**0.13**	**0.16**	**0.18**	**0.11**	**0.34**	**0.26**
C.V (5%)	**-**	**32.24**	**14.91**	**8.91**	**4.44**	**7.40**	**5.02**

The number of tillers per plant at monthly intervals in *Allium* species grown under different growing conditions is displayed in table 4.2.2 and fig- 4.2. At 210 days of planting, the number of tillers ranged from 3.99 to 8.66.

The number of tillers per plant in *Allium tuberosum* followed an upward trend throughout the period of crop development in both the growth conditions examined throughout the experimentation, with the lowest number of tillers on 30 DAP and the highest number on the last data of sampling, 210 DAP. At 30 DAP, no tiller was seen under both the growing conditions. The open condition demonstrated to be the best in terms of the number of tillers per plant, with more tillers [60 DAP (0.81) to 210 DAP (8.6)]. Plants that were grown in rain shelter had less number of tillers on the corresponding dates (0.74 at 60 DAP and 6 at 210 DAP).

The number of tillers per plant in *Allium chinense* followed an upward trend throughout the period of crop development under both the growth conditions examined throughout the experimentation, with the lowest number of tillers on 30 DAP and the highest number on the last date of sampling, 210 DAP. At 30 DAP, no tiller was seen in both the growing conditions. The open condition demonstrated to be the best in terms of the number of tillers per plant, with more tillers on 60 DAP (0.57) to 210 DAP (8.66). Plants that were grown in a rain shelter had less number of tillers on the corresponding dates (0.16 at 60 DAP and 3.99 at 210 DAP).

Number of tillers determines the yield and also, tillers being the main propagation materials it is important to have a greater number of tillers. Thus, based on our observation we can conclude that both the species produced more number of tillers in open condition and less number of tillers in rain shelter. When comparing the two species, *A. chinense* had more tillers per plant at 210 DAP (8.66) in open condition than *A. tuberosum* (8.6). In rain shelter *A. tuberosum* has more tillers at 210 DAP (6) than *A. chinense* (3.99). Significant difference was noticed for this character in both the species in both the growing conditions and the variation between the growing conditions was less in *Allium tuberosum* than in *Allium chinenese*. In an earlier study, Rathore *et al*. (2019) also noticed significant difference in number of tillers in different *Allium* genotypes and reported that number of tillers in *Allium* genotypes ranged from 0 to 8.

Table 4.2.3: Number of leaves per tiller in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**210 DAP**
A.t (RS)	3.78	4.38	5.20	6.33	7.20	7.88	8.40
A.t (OC)	3.80	4.48	5.25	6.40	7.43	8.28	8.85
A.c (RS)	2.55	2.93	3.38	3.79	4.13	4.97	5.89
A.c (OC)	3.03	3.72	4.29	4.89	5.57	6.08	6.84
C.D (5%)	**0.36**	**0.44**	**0.29**	**0.21**	**0.17**	**0.61**	**0.43**
S.E (d)	**0.16**	**0.20**	**0.13**	**0.10**	**0.08**	**0.28**	**0.19**
C.V (5%)	**6.94**	**7.28**	**4.14**	**2.57**	**1.78**	**5.71**	**3.66**

Allium tuberosum

Allium chinense

Plate 7: Tillering in *Allium tuberosum* and *Allium chinense* under open condition at 150 DAP

Allium tuberosum

Allium chinense

Plate 8: Tillering in *Allium tuberosum* and *Allium chinense* under rain shelter at 150 DAP

Number of leaves per tiller is another yield contributing factor in the leaf *Alliums*. *Allium* species exhibited a wide range of leaves per tiller. Table 4.2.3 and fig- 4.3 displays information on the number of leaves per tiller at monthly intervals in *Allium* species grown under different growing conditions. At 210 days of planting, the number of leaves per tiller ranged from 5.88 to 8.85.

Under both the growth conditions examined throughout the experimentation, the number of leaves per tiller in *Allium tuberosum* followed an upward trend throughout the crop development period, with the lowest number on 30 DAP and the highest number on the last date of sampling, 210 DAP. In terms of number of leaves per tiller, the open condition was the best, with highest number of leaves per tiller on 30 DAP (3.8) to 210 DAP (8.85). on the corresponding dates, plants cultivated in the rain shelter had lowest number of leaves per tiller (3.77 at 30 DAP and 8.4 at 210 DAP).

In both the growth conditions examined throughout the experimentation, the number of leaves per tiller in *Allium chinense* followed an upward trend throughout the crop development period, with the lowest number on 30 DAP and the highest number on the last data of sampling, 210 DAP. Here again, the open condition was the best, with highest number of leaves per tiller on 30 DAP (3.02) to 210 DAP (6.84). On the corresponding dates, plants cultivated in a rain shelter had lowest number of leaves per tiller (2.55 at 30 DAP and 5.88 at 210 DAP).

Thus, based on our observation we can conclude that both the species produced more number of leaves per tiller in open condition and less number of leaves per tiller under rain shelter. When comparing the two species, *A. tuberosum* had more leaves per tiller between 30 and 210 DAP in both growing conditions than *A. chinense*. Significant difference was noticed for this character in both the species under both the growing condition and the variation between the growing condition was less in *Allium tuberosum* than in *Allium chinenese*. Marenco and Reis (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth and he stated that, by increasing shade level, leaves and roots were reduced.

Table 4.2.4: Plant height (cm) in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
A.t (RS)	23.78	25.55	28.50	31.65	35.08	37.95	39.37
A.t (OC)	24.65	27.70	29.83	33.05	36.20	39.25	41.65
A.c (RS)	32.07	36.57	40.83	44.44	48.11	53.30	57.02
A.c (OC)	38.18	43.59	48.70	53.89	58.06	61.61	65.60
C.D (5%)	**1.13**	**1.28**	**0.77**	**0.79**	**0.86**	**0.50**	**1.15**
S.E (d)	**0.51**	**0.58**	**0.35**	**0.36**	**0.39**	**0.23**	**0.52**
C.V (5%)	**2.44**	**2.47**	**1.34**	**1.25**	**1.25**	**0.67**	**1.45**

Plant height recorded in the two *Allium* species grown under different growing conditions at monthly intervals is presented in table 4.2.4 and fig- 4.4. *Allium* species exhibited a wide range of plant height. At 210 days of planting, the plant height ranged from 39.37 cm to 65.6 cm.

In both the growth circumstances evaluated during the course of the experimentation, the plant height in *Allium tuberosum* followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last data of sampling, 210 DAP. In terms of the plant height, the open condition showed to be the best, with more plant height on 30 DAP (24.65 cm) to 210 DAP (41.65 cm). Plants that were cultivated under the rain shelter had less plant height on the respective dates (23.77 cm at 30 DAP and 39.37 cm at 210 DAP).

In both the growth circumstances evaluated during the course of the experimentation, the plant height in *Allium chinense* followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. In terms of the plant height, the open condition showed to be the best, with the highest plant height on 30 DAP

(38.17 cm) to 210 DAP (65.6 cm). Plants that were cultivated under the rain shelter had less plant height on the respective dates (32.07 cm at 30 DAP and 57.02 cm at 210 DAP).

Thus, based on our observations we can conclude that both the species recorded highest plant height in open condition and lowest in rain shelter. When comparing the two species, *A. chinense* had highest plant height between 30 and 210 DAP in both growing conditions than *A. tuberosum*. Significant difference was noticed for this character in both the species under both the growing conditions.

Different *Allium* species

The variability for plant height was also observed by Nurzynska-Wierdak (1997), Kohli (2000) in garlic clones, Jogdande *et al*. (2004) in garlic genotypes and Sengupta *et al*. (2007) in garlic varieties.

Different growing conditions

The current findings contradict those of Kale *et al*. (1997), who found that cucumber vegetative growth was higher in the net house than in the open field. Ganesan (2002) in tomato, whereas Amit (2007) in a various leafy vegetable crops.

Table 4.2.5: Leaf length (cm) in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
A.t (RS)	21.01	22.53	25.11	27.61	30.21	32.68	35.20
A.t (OC)	21.51	24.00	26.63	29.18	31.78	34.48	36.30
A.c (RS)	28.18	31.78	35.22	38.42	42.88	45.19	48.33
A.c (OC)	34.54	38.31	41.40	44.56	47.43	51.46	53.96
C.D (5%)	**0.81**	**1.01**	**0.83**	**0.66**	**0.69**	**0.68**	**1.25**
S.E (d)	**0.37**	**0.46**	**0.38**	**0.30**	**0.31**	**0.31**	**0.57**
C.V (5%)	**1.98**	**2.23**	**1.65**	**1.22**	**1.17**	**1.06**	**1.84**

Data on leaf length in *Allium* species grown under different growing conditions is presented in the table 4.2.5 and fig- 4.5. The two *Allium* species differed with respect to the length of leaf. At 210 days of planting, the leaf length ranged from 35.2 cm to 53.96 cm.

Under both the growth circumstances evaluated during the course of the experimentation, the leaf length in *Allium tuberosum* followed an upward trend throughout the period of crop development, with the lowest recorded on 30 DAP and the highest on the last date of sampling, 210 DAP. In terms of the leaf length, the open condition showed to be the best, with more leaf length on 30 DAP (21.51 cm) to 210 DAP (36.29 cm). Plants that were cultivated under the rain shelter had less leaf length on the respective dates (21.01 cm at 30 DAP and 35.2 cm at 210 DAP).

Under both the growth circumstances the leaf length in *Allium chinense* followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. In terms of the leaf length, the open condition showed to be the best, with more leaf length on 30 DAP (34.54 cm) to 210 DAP (53.96 cm). Plants that were cultivated under the rain shelter had less leaf length on the respective dates (28.18 cm at 30 DAP and 48.33 cm at 210 DAP).

Thus, based on our observations we can conclude that both the species recorded highest leaf length in open condition and lowest in rain shelter. When comparing the two species, *A. chinense* had highest leaf length under both growing conditions than *A. tuberosum*. Significant difference was noticed for this character in both the species in both the growing conditions.

Different *Allium* species

The variability for leaf length was also observed by Kohli (2000) in garlic clones, Jogdande *et al*. (2004) in garlic germplasms and Sengupta *et al*. (2007) in garlic varieties.

Different growing conditions

Marenco and Reis (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth and stated that leaf area was greater in plants grown at 50% shade level than those that were grown under 0 or 70% shade level but relative growth rate was better in shaded than in unshaded plants. Vladimirova *et al*. (1997) stated maximum leaf area and longest leaf was observed in Dracaena under 80 per cent shade level.

Table 4.2.6: Leaf breadth (cm) in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**210 DAP**
A.t (RS)	0.33	0.40	0.45	0.48	0.50	0.52	0.55
A.t (OC)	0.37	0.44	0.48	0.50	0.52	0.55	0.57
A.c (RS)	0.29	0.38	0.42	0.50	0.56	0.63	0.66
A.c (OC)	0.35	0.41	0.51	0.64	0.69	0.73	0.81
C.D (5%)	**0.03**	**0.03**	**0.05**	**0.02**	**0.02**	**0.03**	**0.04**
S.E (d)	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.02**
C.V (5%)	**5.46**	**5.41**	**7.40**	**2.10**	**2.74**	**2.99**	**4.09**

Data on leaf breadth recorded in the *Allium* species grown under different growing conditions at monthly intervals are presented in table 4.2.6 and fig- 4.6. At 210 days of planting, the leaf width ranged from 0.54 cm to 0.8 cm.

Under both the growth circumstances evaluated during the course of the experimentation, the leaf breadth in *Allium tuberosum* followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. Leaf breadth recorded its highest value under open condition 0.36 cm at 30 DAP and 0.57cm at 210 DAP. Plants that were cultivated under the rain shelter had less leaf breadth on the respective dates (0.33 cm at 30 DAP and 0.54 cm at 210 DAP).

In *Allium chinense* too leaf breadth followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. Here again open condition showed to be the best, with a leaf breadth of 0.34 cm at 30 DAP and 0.8cm at 210 DAP. Plants that were cultivated under the rain shelter had less leaf breadth on the respective dates (0.28 cm at 30 DAP and 0.65 cm at 210 DAP).

Thus, based on our observations we can conclude that both the species have highest leaf breadth in open condition and lowest in rain shelter. When comparing the two species, *A. chinense* had highest leaf breadth in both the growing conditions than *A. tuberosum*. Significant difference was noticed for this character in both the species under both the growing conditions. Results were contradiction to those reported by Das (2010) that leaf breadth was influenced by low irradiance.

Table 4.2.7: Leaf area (cm^2) in *A. tuberosum* and *A. chinense* at monthly intervals

Entries	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**210 DAP**
A.t (RS)	3.23	4.92	8.54	11.00	12.51	13.48	13.87
A.t (OC)	3.58	5.90	9.02	11.78	13.25	14.08	14.44
A.c (RS)	5.53	7.50	10.16	13.72	16.37	19.77	22.39
A.c (OC)	8.35	11.42	15.62	19.65	22.38	25.75	28.29
C.D (5%)	**0.40**	**0.86**	**0.84**	**0.88**	**0.81**	**0.60**	**1.13**
S.E (d)	**0.18**	**0.39**	**0.38**	**0.40**	**0.37**	**0.27**	**0.51**
C.V (5%)	**4.92**	**7.42**	**4.95**	**4.01**	**3.24**	**2.12**	**3.66**

Leaf area measures the photosynthetically active area and transpiration area, which influences yield by determining the relative growth rate and net assimilation rate. Leaf area of *Allium* species grown under different growing conditions are presented in Table 4.2.7 and Fig- 4.7. At 210 days after planting, the leaf ranged from 13.97 to 28.34 cm^2.

Under both the growth circumstances evaluated during the course of the experimentation, the leaf area in *Allium tuberosum* followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. Leaf area recorded its highest value under open condition 3.58 cm^2 at 30 DAP and 14.44 cm^2 at 210 DAP. Plants that were cultivated under the rain shelter had less leaf area on the respective dates (3.23 cm^2 at 30 DAP and 13.87 cm^2 at 210 DAP).

In *Allium chinense* too leaf area followed an upward trend throughout the period of crop development, with the lowest on 30 DAP and the highest on the last date of sampling, 210 DAP. Here again open condition showed to be the best, with a leaf area of 8.35 cm^2 at 30 DAP and 28.29 cm^2 at 210 DAP. Plants that were cultivated under the rain shelter had less leaf area on the respective dates (5.53 cm^2 at 30 DAP and 22.39 cm^2 at 210 DAP).

Thus, based on our observations we can conclude that both the species have highest leaf area in open condition and lowest in rain shelter. When comparing the two species, *A. chinense* had highest leaf area in both the growing conditions than *A. tuberosum*. Significant difference was noticed for this character in both the species under both the growing conditions.

Different *Allium* species

Significant difference in leaf area was also observed by Rathore *et al*. (2019) in different underutilized *Alliums*.

Different growing condition

The findings were in direct opposition to Anonymous (1999), who claimed that plants in the shadow had bigger leaf area because cells stretch more to obtain light for photosynthesis.

Marenco and Reis (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth. Leaf area was greater in plants grown at 50% shade level than n those that were grown under 0 or 70% shade level but relative growth rate was better in shaded than in unshaded plants.

Different *Allium* species

All morphological characters viz. plant height, number of tillers, leaves per tiller, number of leaves, leaf length, and leaf breadth all showed a wide range of variance. However, because the samples were from different species and were cultivated under diverse conditions, changes in morphological features are to be expected (Riggi *et al*., 2013; Simó *et al*., 2014). More leaves, tillers, leaves per tiller, plant height, leaf length, and leaf width are desirable characters in these *Allium* species because they not only increase the gross weight of the plant but also increase the leaf yield of the plant, indicating that there is more opportunity for selection to improve these characters.

These findings are similar to those of Neffati (2015), who found morphological variation in *A. roseum* populations in the field. Jafari *et al*. (2017) too got comparable results after evaluating morphological features with high heritability, such as leaf length, leaf dry weight, flowers per umbel and inflorescence width in the accessions of *A. akaka* and *A. elburzense*.

Different growing conditions

According to Gupta (2010), favourable environment conditions especially temperature provides a platform for all basic physiological parameters such as photosynthesis, respiration, nutrient uptake, translocation, pigment formation, reproduction, elongation and many other which in turn cause the better vegetative growth of plants. Moreover, favourable environmental conditions stimulate cell division and cell enlargement in the growing apex of the plant resulting in better growth (Amit, 2007).

The present findings are in contradiction with that of Kale *et al*. (1997) reported that vegetative growth of cucumber in net house was high as compared to open field.

Fig-4.1 Number of leaves at monthly intervals in *Allium* species grown under different growing conditions

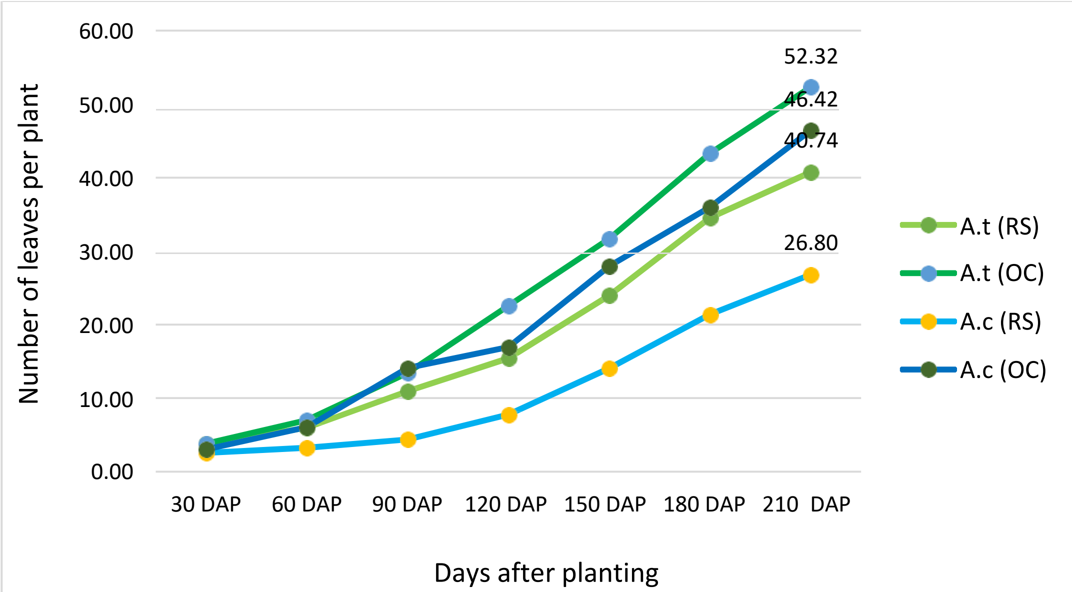


Fig-4.2 Number of tillers at monthly intervals in *Allium* species grown under different growing conditions

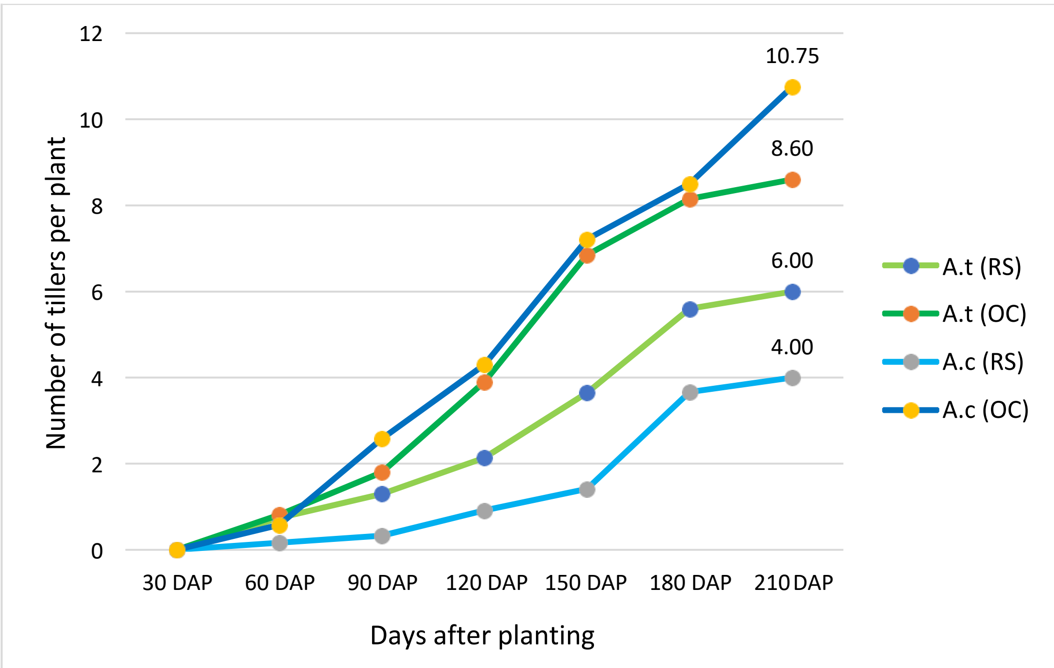


Fig-4.3 Number of leaves per tiller at monthly intervals in *Allium* species grown under different growing conditions

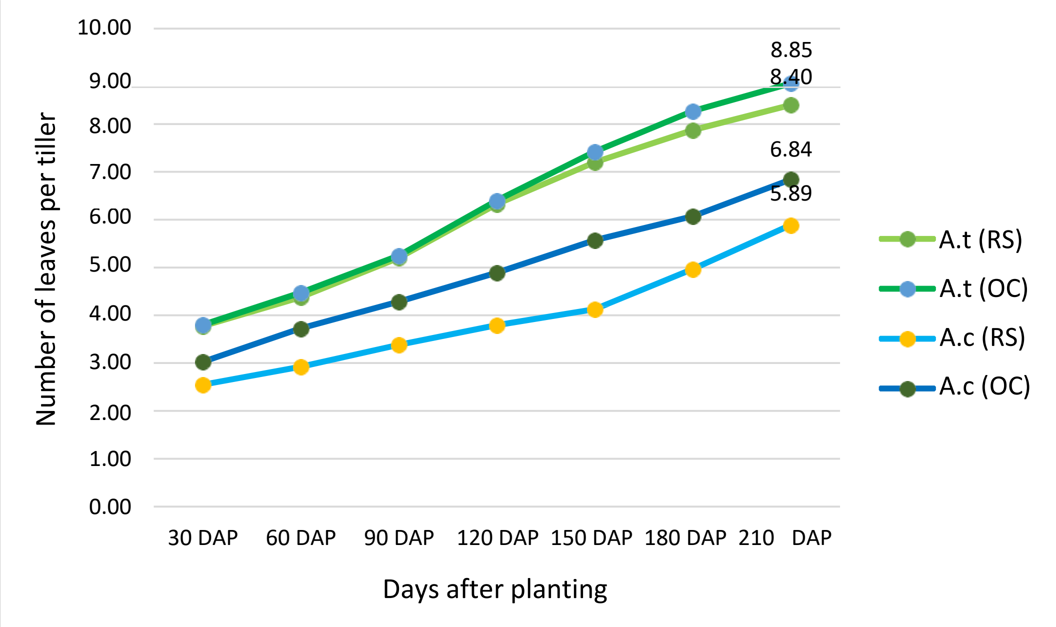


Fig-4.4 Plant height (cm) at monthly intervals in *Allium* species grown under different growing conditions

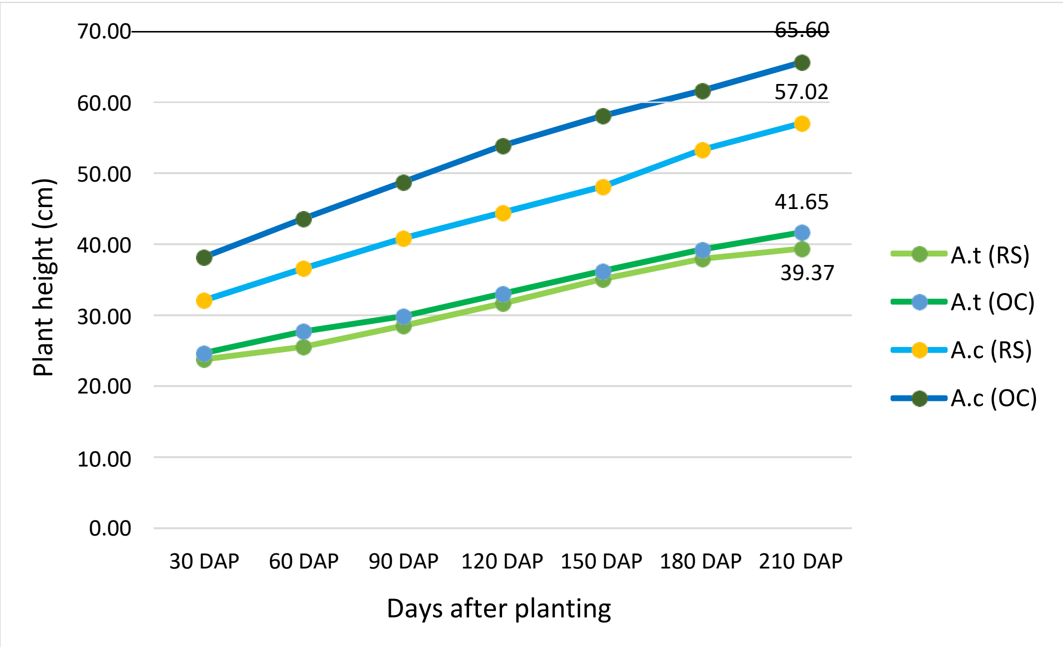


Fig- 4.5 Leaf length at monthly intervals in *Allium* species grown under different growing conditions

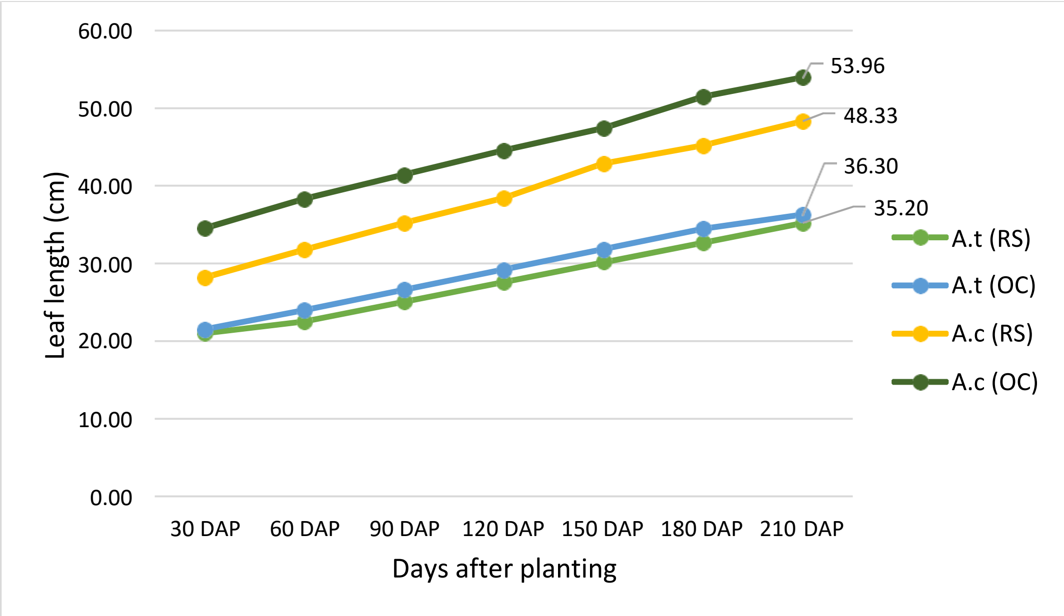


Fig- 4.6 Leaf breadth (cm) at monthly intervals in *Allium* species grown under different growing conditions

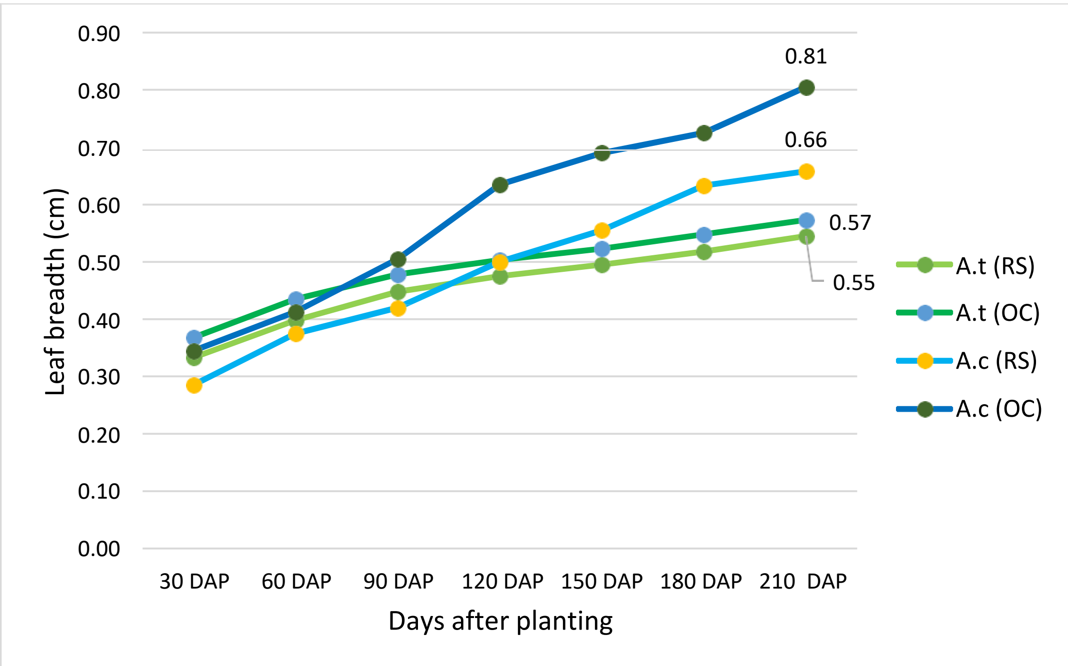
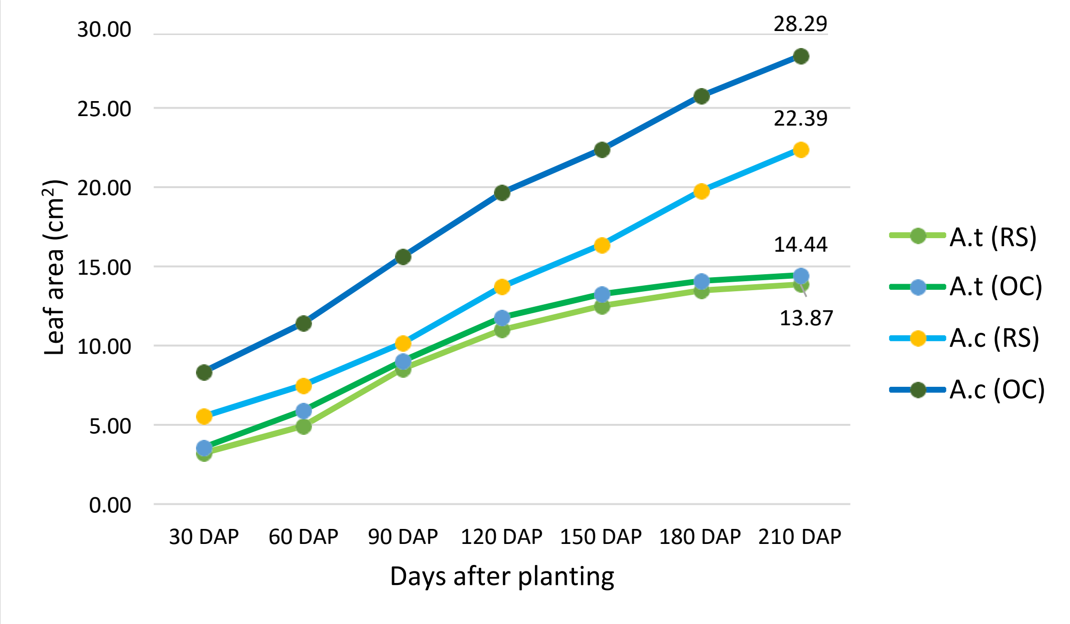


Fig- 4.7 Leaf area (cm^2) at monthly intervals in *Allium* species grown under different growing conditions



4.2.2 Yield characteristics

Table 4.3: Analysis of variance for leaf yield (g/plant)

Sl. No.	Characters	Mean squares	
		Treatments	Error
	df = 2	df = 3	df = 12
1	1^{st} harvest	395.701	1.962
2	2^{nd} harvest	539.741	7.782
3	3^{rd} harvest	507.076	1.195
4	Total yield	4303.25	7.38

Table 4.4: Leaf yield (g/plant) in *Allium* species under different growing conditions

Entries	1st harvest (90 DAP)	2nd harvest (150 DAP)	3rd harvest (210 DAP)	Total yield (g/plant)
A.t (RS)	19.18	24.43	26.23	69.85
A.t (OC)	23.84	27.54	30.08	81.47
A.c (RS)	24.74	29.2	31.04	84.99
A.c (OC)	41.87	49.95	51.25	143.08
C.D (5%)	**2.18**	**4.34**	**1.70**	**4.23**
S.E (d)	**0.99**	**1.97**	**0.77**	**1.92**
C.V (5%)	**5.11**	**8.51**	**3.15**	**2.87**

Fig- 4.8: Leaf yield (g/plant) at 90 days interval in *Allium* species under different growing conditions

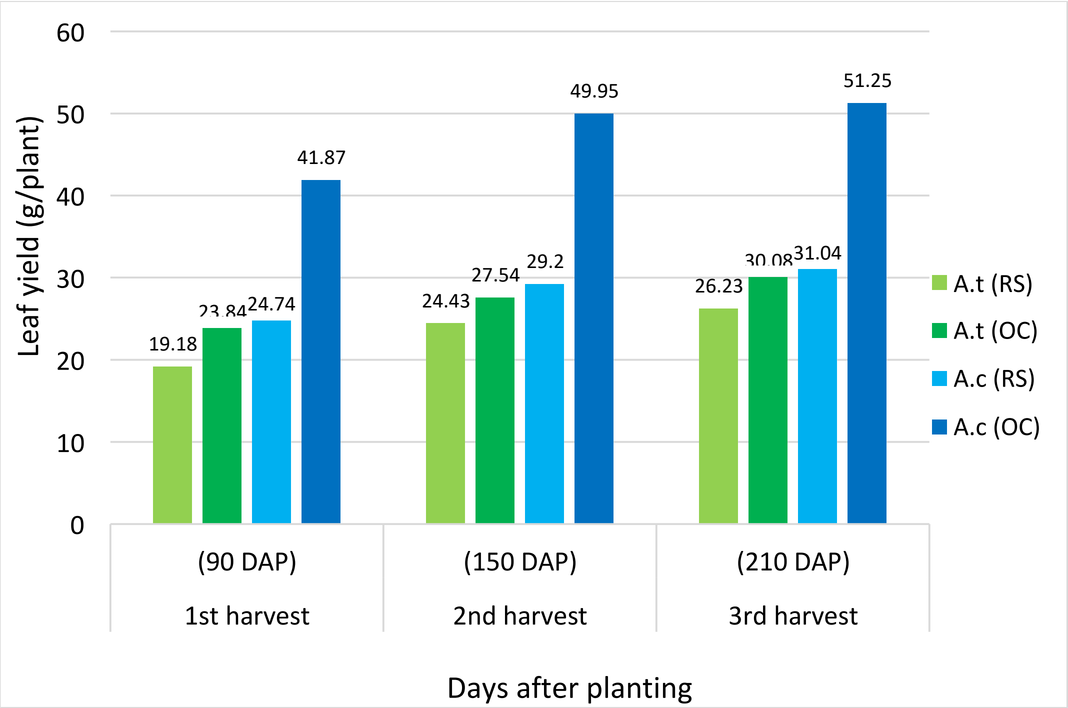
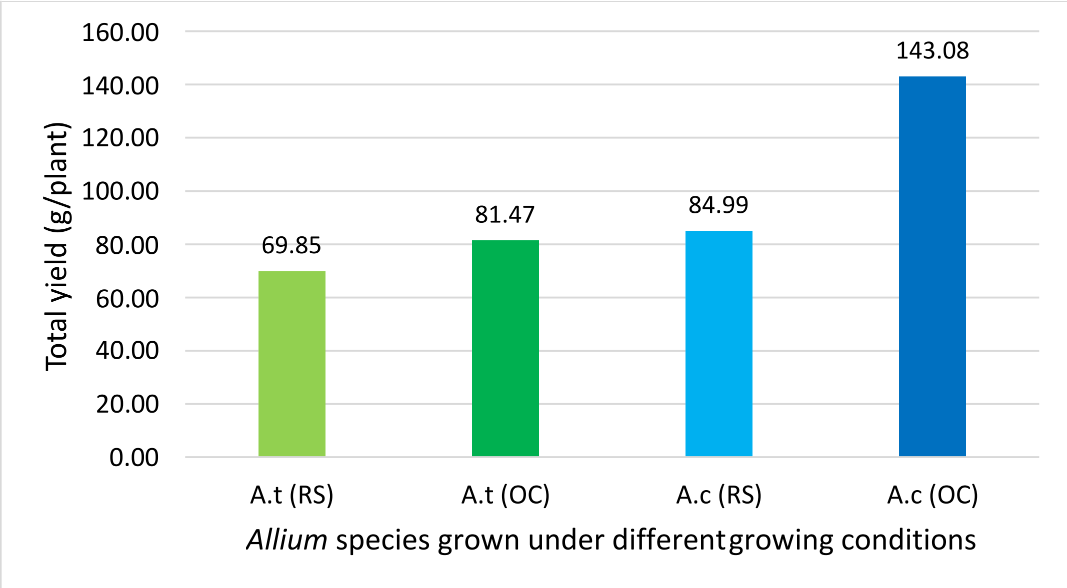


Fig- 4.9: Total foliage yield (g/plant) in *Allium* species under different growing conditions



4.2.4.1 Yield of first cutting (g/plant)

Leaf yield (g/plant) of *Allium* species under study grown under different growing conditions under study is presented in table 4.4 and fig- 4.8. It ranged between 19.18 and 41.87 g/plant.

The data shows that *Allium tuberosum* had significantly highest leaf yield (23.84 g/plant) under open condition and the lowest leaf yield (19.18 g/plant) when grown in rain shelter. *Allium chinense* had significantly highest leaf yield (41.87 g/plant) under open condition and the lowest leaf yield (24.74 g/plant) under rain shelter.

As a result of our findings, we can infer that both the species has highest leaf yield in open condition (*A. tuberosum* – 23.84 g/plant and *A. chinense* – 41.87 g/plant) and least leaf yield in rain shelter (*A. tuberosum* – 19.18 g/plant and *A. chinense* – 24.74 g/plant).

When comparing the two species, *A. chinense* has highest leaf yield than *A. tuberosum*. It shows that the leaf yield in the plants differed significantly depending on the species and the growing conditions.

4.2.4.2 Yield of second cutting (g/plant)

Leaf weight (g/plant) of *Allium* species grown under different growing conditions under study is presented in table 4.4 and fig- 4.8. It ranged between 24.43 and 49.95 g/plant.

It reveals that *Allium tuberosum* has significantly highest leaf yield (27.54 g/plant) under open condition and the lowest leaf yield (24.43 g/plant) when grown in a rain shelter. *Allium chinense* has significantly highest leaf yield (49.95 g/plant) under open condition and the lowest leaf yield (29.2 g/plant) when grown in a rain shelter.

As a result of our findings, we can infer that both the species has highest leaf yield in open condition (*A. tuberosum* – 27.54 g/plant and *A. chinense* – 49.95 g/plant) and least leaf yield in rain shelter (*A. tuberosum* – 24.43 g/plant and *A. chinense* – 29.2 g/plant).

When comparing the two species, *A. chinense* has highest leaf yield than *A. tuberosum*. It shows that the leaf yield in the plants differed significantly depending on the species and the growing conditions.

4.2.4.3 Yield of third cutting (g/plant)

Leaf weight (g/plant) of *Allium* species grown under different growing conditions under study is presented in Table 4.4. It ranged between 26.23 and 51.25 g/plant.

It reveals that *Allium tuberosum* has significantly highest leaf yield (30.08 g/plant) under open condition and the lowest leaf yield (26.23 g/plant) when grown in a rain shelter. *Allium chinense* has significantly highest leaf yield (51.25 g/plant) under open condition and the lowest leaf yield (31.04 g/plant) when grown in a rain shelter.

As a result of our findings, we can infer that both the species has highest leaf yield in open condition (*A. tuberosum* – 30.08 g/plant and *A. chinense* – 51.25 g/plant) and least leaf yield in rain shelter (*A. tuberosum* – 26.23 g/plant and *A. chinense* – 31.04 g/plant).

When comparing the two species, *A. chinense* has highest leaf yield than *A. tuberosum*. It shows that the leaf yield in the plants differed significantly depending on the species and the growing conditions.

4.2.4.4 Total yield (g/plant)

It is evident from yield presented in table 4.4 and fig- 4.9 that variation in respect of yield per cutting in Allium species grown under different growing conditions under study. Total yield per plant varied from 69.85 to 143.08 g/plant.

It reveals that *Allium chinense* has significantly highest leaf yield (143.08 g/plant) under open condition and the lowest leaf yield (84.99 g/plant) when grown in a rain shelter. *Allium tuberosum* has significantly highest leaf yield (81.47 g/plant) under open condition and the lowest leaf yield (69.85 g/plant) when grown in a rain shelter.

As a result of our findings, we can infer that both the species has highest leaf yield in open condition (*A. tuberosum* – 81.47 g/plant and *A. chinense* – 143.08 g/plant) and least leaf yield in rain shelter (*A. tuberosum* – 69.85 g/plant and *A. chinense* – 84.99 g/plant).

When comparing the two species, *A. chinense* has highest leaf yield than *A. tuberosum*. It shows that the leaf yield in the plants differed significantly depending on the species and the growing conditions.

Allium tuberosum

Allium chinense

Plate 9: Harvested plant of *A. tuberosum* and *A. chinense* under rain shelter and open condition at 210 DAP

Different *Allium* species

Adamczewka *et al*. (2016) published a study on the yield and biological value of garlic chives (*Allium tuberosum* Rottl. EX Spreng). They reported that the leaf yield varied in different year and increased significantly over the years of cultivation which could be attributed to the milder temperatures and higher total rainfall in the first half of the plant growth season.

According to Uddin *et al*. (2019), twice application of thiourea treatment resulted in maximum yield/plant (17.33g), yield/plot (513 g), and yield/ha (13.86 t) (TU2). Based on the overall results, thiourea twice (TU2) has the potential to produce garlic chives.

Different growing condition

These findings contradict Amit (2007), who indicated that in various leafy vegetable crops, protected environments are a strategy for giving favourable environmental or growth conditions to the plants, and that greater yield was gained in protected structures than in open fields.

Table 4.5: Analysis of variance for physiological characteristics

Sl. No.	Characters	Mean squares	
		Treatments	**Error**
	df = 7	**df = 3**	**df = 12**
1	Total chlorophyll	0.021	0.001
2	Chlorophyll ‘a’	0.009	0.001
3	Chlorophyll ‘b’	0.003	0
4	Total carotenoids	0.267	0.07
5	Dry matter	325.74	3.67
6	Moisture content	325.74	3.83
7	Relative water content	250.1	3.33
8	TSS	3.62	0.09

Table 4.6: Physiological traits in *Allium* species under different growing conditions

Entries	Total chlorophyll (mg/g)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)	Total carotenoids (mg/100g)	Dry matter (%)	Moisture content (%)	Relative water content (%)	TSS (%)
A.t (RS)	0.66	0.28	0.38	1.52	18.43	81.57	87.23	8.6
A.t (OC)	0.54	0.2	0.34	1.32	23.64	76.36	84.32	9
A.c (RS)	0.58	0.22	0.36	1.28	34.6	65.4	74.1	10.2
A.c (OC)	0.49	0.17	0.32	0.91	37.56	62.44	70.78	10.6
C.D (5%)	**0.05**	**0.04**	**0.03**	**0.13**	**2.98**	**3.05**	**2.84**	**0.46**
S.E (d)	**0.02**	**0.02**	**0.01**	**0.06**	**1.35**	**1.38**	**1.29**	**0.21**
C.V (5%)	**5.09**	**12.02**	**5.22**	**6.63**	**6.71**	**2.74**	**2.31**	**3.10**

Fig- 4.10: Physiological parameters (Total chlorophyll, chlorophyll 'a' and chlorophyll 'b') in *Allium* species under different growing conditions

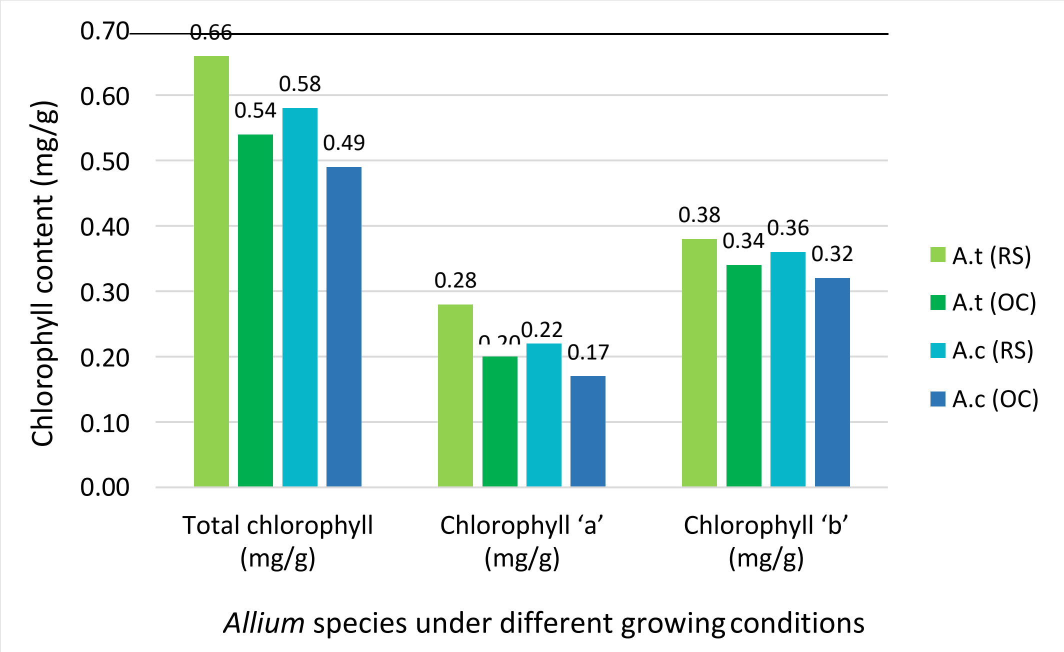


Fig- 4.11: Total carotenoids content in *Allium* species under different growing conditions

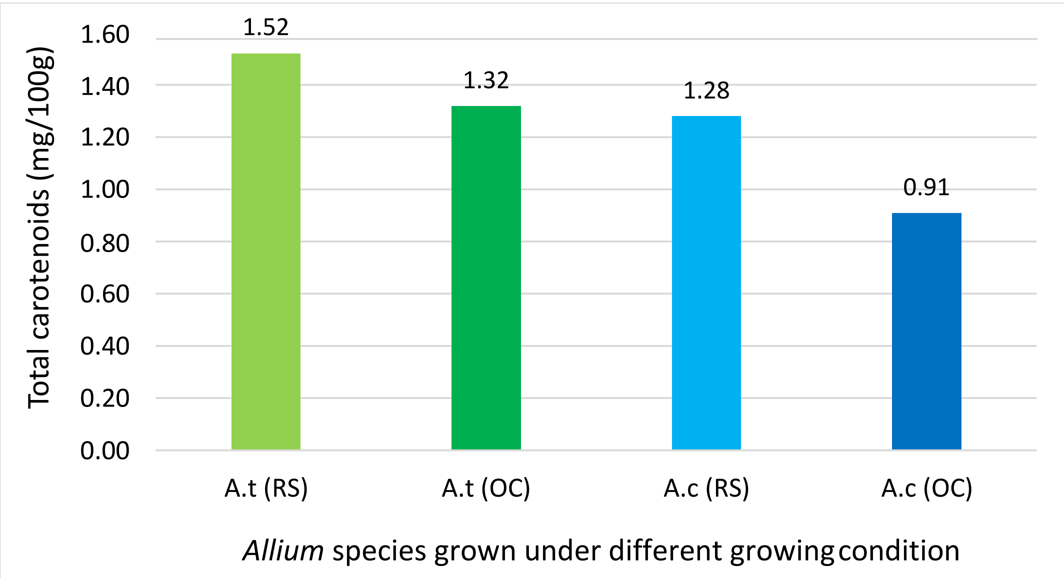
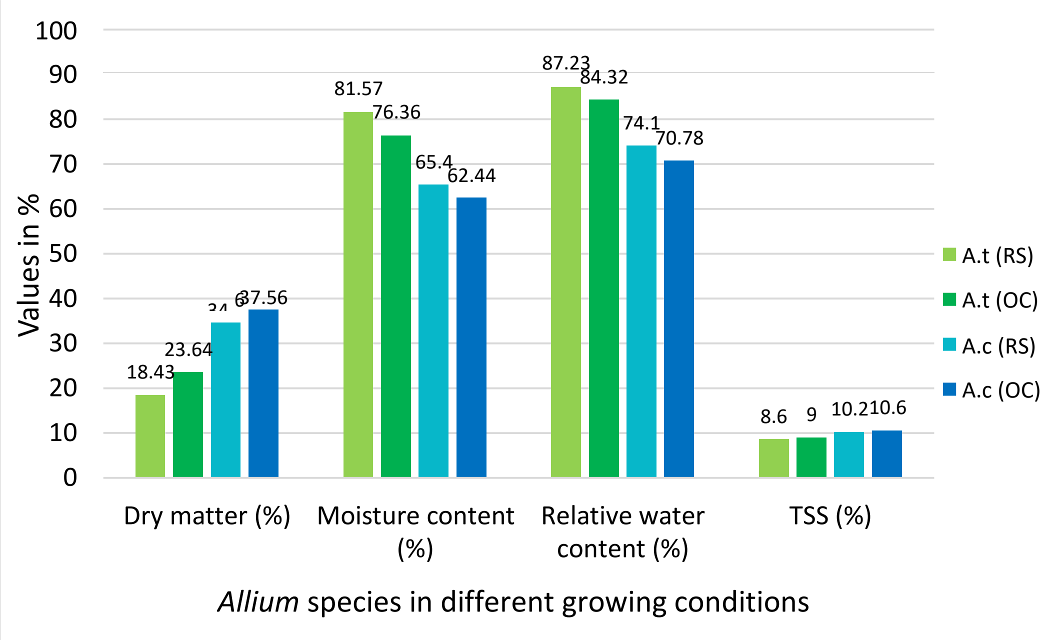


Fig- 4.12: Physiological parameters (Dry matter, Moisture content, Relative water content, TSS) in *Allium* species under different growing conditions



4.2.3 Physiological characteristics

Total chlorophyll, chlorophyll 'a', chlorophyll 'b', dry matter, moisture content, relative water content and TSS are the physiological traits analysed in the study.

4.2.3.1 Total chlorophyll content

Chlorophyll is a complex biomolecule that is responsible for photosynthesis, which allows plants to grow and determines yield. Table 4.6 and fig-4.10 gives the total chlorophyll content of two *Allium* species grown under different growing conditions under investigation. The amount of total chlorophyll ranged from 2.1 to 4.32 g/ml.

Allium tuberosum recorded significantly highest total chlorophyll content (0.66 mg/g) under rain shelter and the lowest total chlorophyll content (0.54 mg/g) when grown under open condition. *Allium chinense* had significantly highest total chlorophyll content (0.58 mg/g) under rain shelter and the lowest total chlorophyll content (0.49 mg/g) when grown under open field condition.

Thus, based on our observations we can conclude that both species recorded higher total chlorophyll content in rain shelter (*A. tuberosum* – 0.66 mg/g and *A. chinense* – 0.58 mg/g) and lower values under open condition (*A. tuberosum* – 0.54 and *A. chinense* – 0.49 mg/g). When comparing the two species, *A. tuberosum* has higher total chlorophyll content than *A. chinense*. Significant difference was noticed for this character in both the species and in both the growing conditions.

Different *Allium* species

Significant difference in total chlorophyll content was also noticed by Stajner and Varga (2003) in different *Allium* species.

Different growing conditions

Similar results were observed by Lykas and Katsoulas (2012) and reported that shade nets increases the chlorophyll content in compact gardenia potted plants. Low light efficiently draws higher chlorophyll concentration and reduces the chlorophyll a/b ratio by utilising light energy (Taiz and Zeiger 2006).

Photosynthesis requires an adequate quantity of light; yet, crops that receive excessive light may be stressed and lower their output by shutting their stomata. Sunburn can occur on leaves exposed to high amounts of direct sunlight, reducing the marketable yield significantly. More shade, on the other hand, may result in lower productivity and quality as a result of less light (Hemming, 2009).

Sunlight is the primary source of energy for photosynthesis and transpiration in plants, and it is also important in determining tissue temperature, which has implications for metabolic process speeds and balance (Jones, 1992).

4.2.3.2 Chlorophyll ‘a’

The chlorophyll ‘a’ content of two *Allium* species grown under different growing conditions under study are shown in table 4.6 and fig- 4.10. The amount of chlorophyll ‘a’ in the samples ranged from 1.01 to 1.74 g/ml.

It reveals that *Allium tuberosum* had significantly highest chlorophyll ‘a’ content (0.28 mg/g) in rain shelter and the lowest chlorophyll ‘a’ content (0.2 mg/g) when grown under open condition. *Allium chinense* too recorded significantly highest chlorophyll ‘a’ content (0.22 mg/g) in rain shelter and the lowest chlorophyll ‘a’ content (0.17 mg/g) when grown under open condition.

Thus, based on our observations we can conclude that both species possessed higher chlorophyll ‘a’ concentration in rain shelter (*A. tuberosum* – 0.28 mg/g and *A. chinense* – 0.22 mg/g) and lower chlorophyll ‘a’ concentration under open condition (*A. tuberosum* – 0.2 and *A. chinense* – 0.17 mg/g). Between the species, *A. tuberosum* had higher chlorophyll 'a' content than *A. chinense*. Significant difference was noticed for this character in both the species and under both the growing conditions.

Different *Allium* species

Significant difference in Chlorophyll ‘a’ content was also noticed by Stajner and Varga (2003) in different *Allium* species. Sultana *et al*. (2015) reported 0.32 ± 0.04 % of chlorophyll ‘a’ in *A. tuberosum*.

Different growing conditions

According to Salisbury and Ross (1991), shade plants have more chlorophyll 'b' than chlorophyll 'a,' where chlorophyll 'b' is a yellowish green and chlorophyll 'a' is a blue green. Dark green leaves are produced by plants with a higher chlorophyll 'b' to chlorophyll 'a' ratio.

4.2.3.3 Chlorophyll ‘b’

The chlorophyll ‘b’ content of two *Allium* species grown under different growing conditions under study is shown in table 4.6 and fig- 4.10. The amount of chlorophyll ‘b’ in samples ranged from 0.32 to 0.38 mg/g.

It reveals that *Allium tuberosum* had significantly highest chlorophyll ‘b’ content (0.38 mg/g) when grown in rain shelter and the lowest chlorophyll ‘b’ content (0.34 mg/g) under open condition. *Allium chinense* too had significantly highest chlorophyll ‘b’ content (0.36 mg/g) when grown in rain shelter and the lowest chlorophyll ‘b’ content (0.32 mg/g) under open condition.

Thus, based on our observations we can conclude that both species exhibited higher chlorophyll ‘b’ concentration in rain shelter (*A. tuberosum* – 0.38 mg/g and *A. chinense* – 0.36 mg/g) and lower chlorophyll ‘b’ concentration under open condition (*A. tuberosum* – 0.34 and *A. chinense* – 0.32 mg/g). When comparing the two species, *A. tuberosum* has higher chlorophyll 'a' content than *A. chinense*. Significant difference was noticed for this character in both the species and in both the growing conditions.

Different *Allium* species

Significant difference in Chlorophyll ‘a’ content was also noticed by Stajner and Varga (2003) in different *Allium* species. Sultana and Mohsin (2014) reported 0.26 ± 0.03% of chlorophyll ‘b’ in *A. tuberosum*.

Different growing conditions

According to Salisbury and Ross (1991), shade plants have more chlorophyll 'b' than chlorophyll 'a,' where chlorophyll 'b' is a yellowish green and chlorophyll 'a' is a blue green. Dark green leaves are produced by plants with a higher chlorophyll 'b' to chlorophyll 'a' ratio.

4.2.3.4 Total carotenoids (g/100g)

Total carotenoids content of *Allium* species grown under different growing conditions under study is presented in table 4.6 and fig- 4.11. It ranged between 0.91 and 1.52 mg/100g. The quantity of total carotenoids in the plants differed significantly depending on the species and the growing conditions.

It reveals that *Allium tuberosum* had significantly highest quantity of total carotenoids (1.52 mg/100g) when grown in rain shelter and the lowest quantity of total carotenoids (1.32 mg/100g) when grown under open condition. *Allium chinense* had significantly highest quantity of total carotenoids (1.28 mg/100g) in rain shelter and the lowest quantity of total carotenoids (0.91 mg/100g) when grown under open condition.

Thus, based on our observations we can conclude that both the species had highest quantity of total carotenoids in rain shelter (*A. tuberosum* – 1.52 mg/100g and *A. chinense* – 1.28 mg/100g) and lowest quantity of total carotenoids in open condition (*A. tuberosum* – 1.32 mg/100g and *A. chinense* – 0.91 mg/100g).

When comparing the two species, *A. tuberosum* had highest total carotenoids content than *A. chinense*. The quantity of total carotenoids in the plants differed significantly depending on the species and the growing conditions. Carotenoids are the part of photosynthesis complexes (Croce *et al*., 1999a, 1999b). They function as photo protectants by channeling photons to the photosynthetic reaction centre and neutralizing harmful free radicals (Croce *et al*., 1999b; Niyogi, 1999).

Different *Allium* species

Umehara *et al*. (2006) found 4.63 mg/100 g FW of β-carotene in the leaves of *A. fistulosum* L. cv. Kujyoasagikei. In the leaf tissues of *A. fistulosum*, total carotenoids were found to be 2.87 mg/g FW (Stajner *et al*., 2006); *A. fistulosum* has an average of 0.60 mg/100 g FW of β- carotene and 1.14 mg/100 g FW of lutein + zeaxanthin, according to the USDA Nutrient Database, 2008.

Different growing conditions

Growing site and accession had little effect on carotenoid and chlorophyll pigments in leaf tissue, according to the USDA Nutrient Database, 2008.

4.2.3.5 Dry matter (%)

Dry matter content determines the yield by determining the relative growth rate and net assimilation rate and it determines the nutrient content. The dry matter percentage of *Allium* species grown under different growing conditions under study is presented in table 4.6 and fig- 4.12.

It reveals that *Allium tuberosum* had significantly highest dry matter percentage (23.64%) under open condition and the lowest dry matter percentage (18.43%) when grown in rain shelter. *Allium chinense* had significantly highest dry matter percentage (37.56%) under open condition and the lowest dry matter percentage (34.6%) when grown in rain shelter.

Thus, based on our observations we can conclude that both species exhibited higher dry matter content in open condition (*A. tuberosum* – 23.64 % and *A. chinense* – 37.56%) and lower dry matter content under rain shelter (*A. tuberosum* – 18.43% and *A. chinense* – 34.6%). When comparing the two species, *A. chinense* had higher dry matter percentage than *A. tuberosum*. Significant difference was noticed for this character in both the species and in both the growing conditions.

Different *Allium* species

Adamczewka *et al*. (2016) has reported 10.73% of dry matter in garlic chives. Żurawik and Jadczak (2008) reported 12.1 - 14.1% of dry matter in the leaves *A. tuberosum.* According to Dyduch and Najda (2000), the dry matter content of immature garlic leaves ranged from 10.68 to 15.82 percent. Jadczak (2003) has reported 9.64% of dry matter in leaves of tree onion. Sultana and Mohsin (2014) has reported 7.82 ± 0.36 % dry matter content in *A. tuberosum*.

Different growing condition

Marenco and Reis (1998) conducted pot experiment to study the effect of shade levels (0, 50 and 70%) on wrinkled grass (*Ischaemum rugosum*) growth. Leaf thickness was lower in plants cultivated at high shade levels than in open conditions and also observed reduction in dry matter accumulation in leaves, roots and culms by increasing shade levels.

The findings supported those of Cervelli *et al*. (2002), who found that as shade level increased, fresh weight and specific dry weight dropped. In contrast, Gaurav *et al*. (2015) reported that cordyline leaf dry weight was highest under 75 percent shade, followed by 50 percent shade.

4.2.3.6 Moisture content (%)

Moisture content of the two *Allium* species grown under different growing conditions under investigation is presented in table 4.6 and fig- 4.12. The moisture content varied between 62.44 and 81.57 percent.

Data reveals that *Allium tuberosum* had significantly highest moisture content (81.57 %) under rain shelter and the lowest moisture content (76.36%) when grown in an open condition. *Allium chinense* too had significantly highest moisture content (65.4%) under rain shelter and the lowest moisture content (62.44%) when grown in an open condition.

Thus, based on our observations we can conclude that both species have greater moisture content under rain shelter (*A. tuberosum* – 81.57 percent and *A. chinense* – 65.4 percent) and lower moisture content in open condition (*A. tuberosum* – 76.36 percent and *A. chinense* – 62.44 percent). When comparing the two species, *A. tuberosum* has higher moisture content than *A. chinense*. Open field will naturally have less moisture in leaves due to maximum transpiration when compared to rain shelter where only reduced rate of transpiration is expected.

Significant difference was noticed for this character in both the species and in both the growing condition.

Different *Allium* species

Khalid *et al*. (2014) also observed significant difference in moisture levels of *Allium tuberosum* and *Allium sativum*, with moisture levels ranging from 64.07±0.81 to 62.19±0.82 percent, respectively. Sultana and Mohsin (2014) has reported 92.18 ± 0.36 % moisture content in *A. tuberosum*.

The observations were also similar to the results of Rathore *et al*. (2019) in *A. tuberosum* (84.39%) and *A. chinense* (59.22%).

4.2.3.7 Relative water content (%)

Table 4.6 and fig- 4.12 gives the relative water content of *Allium* species grown under different growing conditions under study. The relative water content varied between 64.78 and 87.23 percent.

It reveals that *Allium tuberosum* has significantly highest relative water content (87.23 %) when grown in a rain shelter and the lowest relative water content (84.32%) under open condition. *Allium chinense* had significantly highest relative water content (74.1 when grown in rain shelter and the lowest relative water content (70.78%) under open condition.

Thus, based on our observations we can conclude that both species exhibited higher relative water content in rain shelter (*A. tuberosum* – 87.23 % and *A. chinense* – 74.1%) and lower relative water content under open condition (*A. tuberosum* – 84.32% and *A. chinense* – 70.78 %). When comparing the two species, *A. tuberosum* had higher relative water content than *A. chinense*. Significant difference was noticed for this character in both the species and in both the growing conditions. The results were in accordance with the moisture content.

The balance between water supply to the leaf tissue and transpiration rate is expressed in the relative water content (RWC) of leaves, which is an essential measure of water status in plants (Lugojan and Ciulca, 2011).

Different *Allium* species

In an earlier study, Rathore *et al*. (2019) reported that relative water content in underutilized *Alliums* was significantly higher compared to *Allium cepa*.

4.2.3.8 Total soluble solid (%)

Total soluble solid of *Allium* species grown under different growing conditions under study are presented in table 4.6 and fig- 4.12. The total soluble solid content varied between 8.6 and 10.6 percent.

It reveals that *Allium tuberosum* has significantly highest total soluble solid content (9 percent) under open condition and the lowest total soluble solid content (8.6 percent) when grown in a rain shelter.

It reveals that *Allium chinense* too recorded significantly highest total soluble solid content (10.6 percent) under open condition and the lowest total soluble solid content (10.2 percent) when grown in rain shelter.

Thus, based on our observations we can conclude that both species exhibited higher total soluble solid content in open condition (*A. tuberosum* – 9 % and *A. chinense* – 10.6%) and lower total soluble solid content under rain shelter (*A. tuberosum* – 8.6% and *A. chinense* – 10.2 %). When comparing the two species, *A. chinense* had higher total soluble solid content than *A. tuberosum*. Significant difference was noticed for this character in both the species and in both the growing conditions. TSS is a potentially essential trait in general because soluble solids help to generate taste, which is a more or less important quality attribute depending on the product. It was shown to be linked to the long-term retention of a pleasant flavour in leafy vegetable (Varoquaux *et al*., 1996; Martínez, 2010).

Different *Allium* species

Khalid *et al.* (2014) also observed significant difference in TSS content of *Allium tuberosum* and *Allium sativum*. The TSS was higher in *A. tuberosum* in comparison to garlic.

Different growing conditions

According to Andriolo *et al*. (2005), environmental parameters such as temperature, fertiliser, light, and plant density have a significant impact on total soluble solids levels.

4.2.4 Biochemical characteristics

Table 4.7: Analysis of variance for biochemical characteristics

Sl. No.	Characters	Mean squares	
		Treatments	Error
	df = 6	df = 3	df = 12
1	Ascorbic acid	91.54	4.94
2	Phenol	0.25	0
3	Flavonoids	0.44	0.04
4	Total sugar	72.08	2.33
5	Reducing sugar	27.83	2.47
6	Non reducing sugar	10.07	0.52
7	Sulphur	0.02	0

Table 4.8: Biochemical characteristics in *Allium* species under different growing conditions

Entries	**Ascorbic acid (mg/100g)**	**Phenol (mg/g)**	**Flavonoids (mg/g)**	**Total sugars (%)**	**Reducing sugar (%)**	**Non reducing sugar (%)**	**Sulphur (%)**
A.t (RS)	18.74	0.6	3	19.60	13.84	5.76	0.95
A.t (OC)	26.5	0.8	3.4	20.94	14.14	6.80	0.97
A.c (RS)	23.86	0.9	2.9	26.30	17.72	8.33	0.8
A.c (OC)	30.11	1.2	3.6	28.49	19.16	9.33	0.85
C.D (5%)	**3.46**	**0.03**	**0.32**	**2.38**	**2.45**	**1.12**	**0.04**
S.E (d)	**1.57**	**0.01**	**0.15**	**1.08**	**1.11**	**0.51**	**0.02**
C.V (5%)	**8.96**	**2.09**	**6.46**	**6.41**	**9.69**	**9.51**	**2.65**

Fig- 4.13: Ascorbic acid content in *Allium* species under different growing conditions

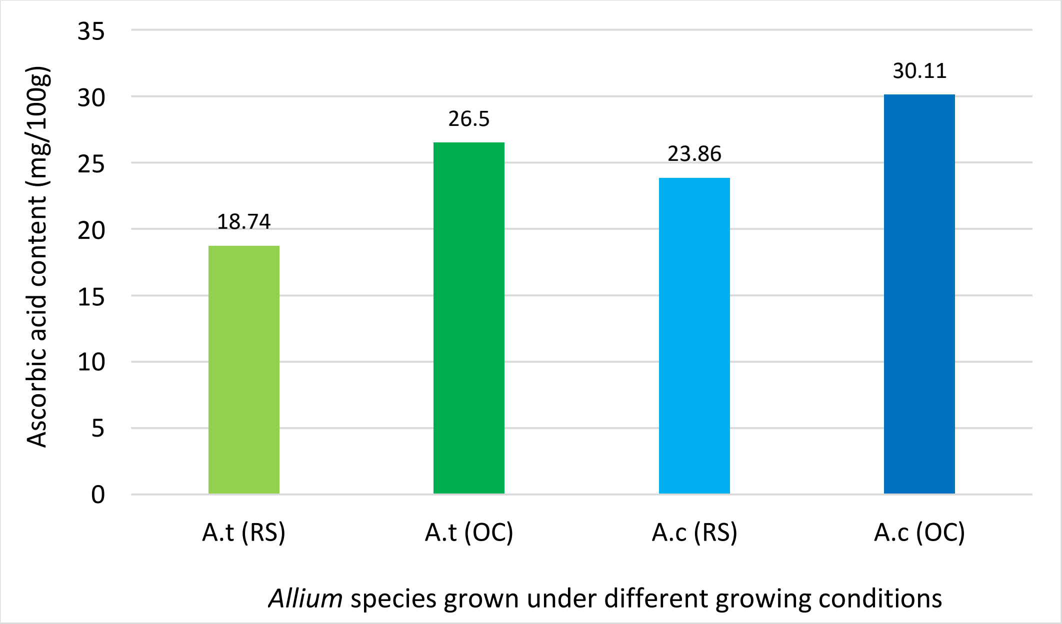


Fig- 4.14: Total phenol content in *Allium* species under different growing conditions

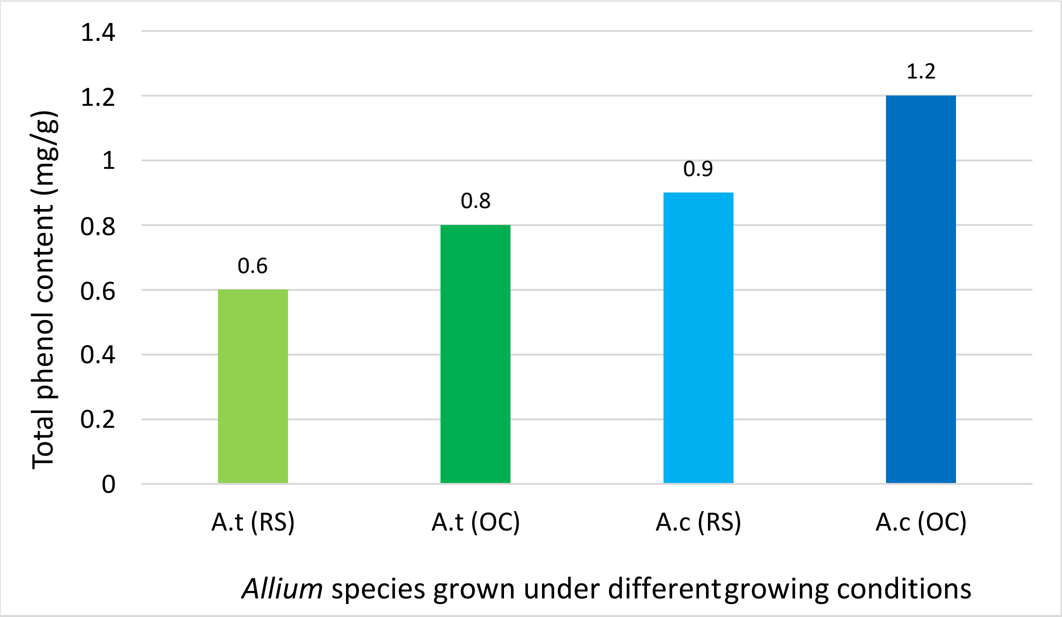


Fig- 4.15: Total flavonoids content in *Allium* species under different growing conditions

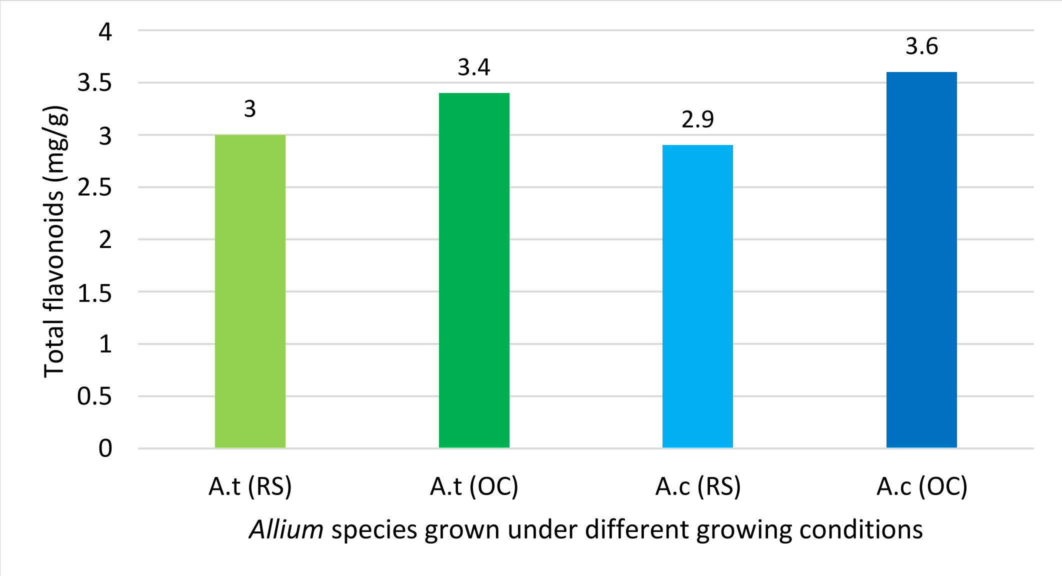


Fig- 4.16: Biochemical parameters (Total sugar, reducing sugar and non-reducing sugar) in *Allium* species under different growing conditions

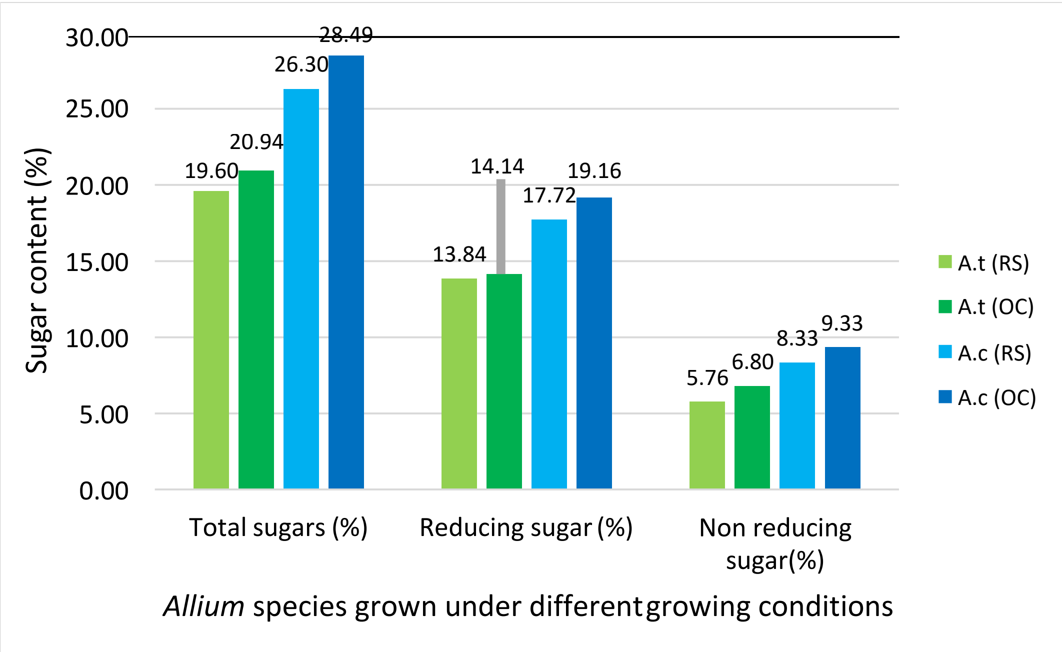
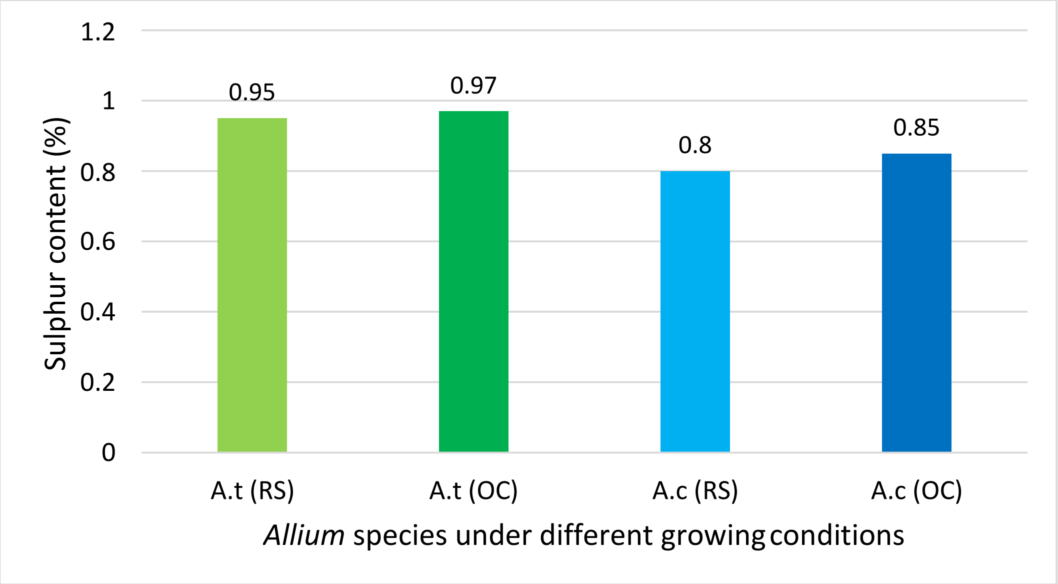


Fig- 4.17: Sulphur content (%) in *Allium* species under different growing conditions



4.2.4 Biochemical characteristics

4.2.4.1 Ascorbic acid (mg/100g)

All bodily tissues require vitamin C, commonly known as ascorbic acid, for growth, development, and repair. It is an important antioxidant vitamin. It's engaged in a variety of biological processes, including collagen formation, iron absorption, immune system function, wound healing, and the maintenance of cartilage, bones, and teeth. Ascorbic acid content of *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.13. It ranged between 18.74 to 30.11 mg/100g.

Data reveals that *Allium tuberosum* has significantly highest ascorbic acid content (26.5 mg/100g) under open condition and the lowest ascorbic acid content (18.74 mg/100g) when grown in rain shelter. *Allium chinense* too had significantly highest ascorbic acid content (30.11 mg/100g) under open condition and the lowest ascorbic acid content (23.86 mg/100g) when grown in rain shelter.

Thus, based on our observations we can conclude that both species exhibited higher ascorbic acid content in open condition (*A. tuberosum* – 26.5 mg/100g and *A. chinense* – 30.11 mg/100g) and lower ascorbic acid content under rain shelter (*A. tuberosum* – 18.74 mg/100g and *A. chinense* – 23.86 mg/100g). When comparing the two species, *A. chinense* had highest ascorbic acid content than *A. tuberosum*. Significant difference was noticed for this character in both the species and in both the growing condition.

Different *Allium* species

This outcome agrees with the findings of Stajner and Varga (2003) in *Allium* species and Thangasmy *et al*. (2018) in onion. Adamczewka *et al*. (2016) has reported 540.9 mg kg^{-1} f.m. of vitamin C in garlic chives. Dyduch and Najda (2000) reported 7.58 mg 100 g^{-1} f.m of ascorbic acid content in immature garlic leaves. Żurawik and Jadczak (2008) reported 43.0 - 56.1 mg 100 g^{-1} of L-ascorbic acid in the leaves *A. tuberosum* and Jadczak (2003) reported 63.61 mg 100 g^{-1} of vitamin C in leaves of tree onion. Rodkiewicz (2013) observed 53 and 140 mg 100 g^{-1} f.m. in leaves of *A. schoenoprasum.*

Different growing condition

According to Kolota *et al.* (2013), covering plants of japanese bunching onion with a perforated foil negatively influenced the amounts of vitamin C as compared to those cultivated without covers.

4.2.4.2 Total phenols (mg/g)

Phenols are powerful antioxidants that will protect biomolecules like DNA, proteins, and lipids from oxidative damage, which is linked to chronic illnesses including cancer and cardiovascular disease. Phenol content of *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.14. It ranged between 0.6 and 1.2 mg/g.

Data shows that *Allium tuberosum* had significantly highest phenol content (0.8 mg/g) under open condition and the lowest phenol content (0.6 mg/g) when grown in rain shelter. *Allium chinense* had significantly highest phenol content (1.2 mg/g) under open condition and the lowest phenol content (0.9 mg/g) when grown in rain shelter.

Thus, based on our observations we can conclude that both species exhibited higher phenol content in open condition (*A. tuberosum* – 0.8 mg/g and *A. chinense* – 1.2 mg/g) and least phenol content under rain shelter (*A. tuberosum* – 0.6 mg/g and *A. chinense* – 0.9 mg/g). Between two species, *A. chinense* had highest phenol content than *A. tuberosum*. Significant difference was noticed for this character in both the species and in both the growing conditions.

Different *Allium* species

According to Rathore *et al*. (2019), total phenol concentration in underexploited *Alliums* was much higher than that of *Allium cepa* (4.03 mg/g). Arfa *et al*. (2015) reported that the total phenol content of 10 leek accessions ranged from 16 to 21mg GAE/g dry weight and 16 to 48 mg GAE/g dry weight in the bulbs and leaves respectively which can be comparable with our findings. Khalid *et al.* (2014) also observed significant difference in total phenolic contents of *A. tuberosum* and *A. sativum*. In compared to *A. sativum* (0.39±0.10 mg GAE/g fresh weight), *A. tuberosum* had a higher phenolic content (0.61±0.10 mg GAE/g fresh weight).

4.2.4.3 Total flavonoids (mg/g)

Allium flavonoids contain anticancer, antioxidant, anti-diabetic, cardioprotective, hypolipidemic, neuroprotective, and antimicrobial properties (Kothari, *et al*. 2020). Flavonoid content of *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.15. It ranged between 2.9 and 3.6 mg/g.

It reveals that *Allium tuberosum* had significantly highest amount of flavonoids (3.4 mg/g) under open condition and the lowest amount of flavonoids (3 mg/g) when grown in a rain shelter. *Allium chinense* too recorded significantly highest amount of flavonoids (3.6 mg/g) under open condition and the lowest amount of flavonoids (2.9 mg/g) when grown in rain shelter.

Thus, based on our observations we can conclude that both the species gave highest amount of flavonoids in open condition (*A. tuberosum* – 3.4 mg/g and *A. chinense* – 3.6 mg/g) and least flavonoids content in rain shelter (*A. tuberosum* – 3 mg/g and *A. chinense* – 2.9 mg/g). When comparing the two species, *A. chinense* has highest flavonoid content than *A. tuberosum*. The quantity of flavonoid in the plants differed significantly depending on the species and the growing conditions. Stajner *et al*. (2003) reported highest total flavonoid content (496.53 mg/g) in onion leaves and 37.87mg/g in *A. flavum* leaves. According to Rathore *et al*., 2020, total flavonoids concentration in underutilized *Alliums* was substantially greater than *Allium cepa* (1.43 mg/g). Arfa *et al*. (2015) reported that the flavonoids content of 10 leek accessions ranged from 1.01 to 5.84 mg CE/g DW in the bulbs and from 4.10 to 4.40 mg CE/g DW in the leaves, respectively.

4.2.4.4 Total sugar (mg/g)

Total sugar content of *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.16. It ranged between 19.6 and 28.49 percent.

Data clearly indicates that *Allium tuberosum* had significantly highest amount of total sugar (20.94 percent) under open condition and the lowest amount of total sugar (20.94 percent) when grown in rain shelter. *Allium chinense* also had significantly highest amount of total sugar (28.49 percent) under open condition and the lowest amount of total sugar (26.3 percent) when grown in rain shelter.

Thus, based on our observations we can conclude that both the species had highest amount of total sugar in open condition (*A. tuberosum* – 20.94 percent and

A. chinense – 28.49 percent) and least amount of total sugar in rain shelter (*A. tuberosum* – 19.6 percent and *A. chinense* – 26.3 percent).

Between two species, *A. chinense* had highest amount of total sugar than *A. tuberosum*. The quantity of total sugar in the plants differed significantly depending on the species and the growing conditions.

Different *Allium* species

Dyduch and Najda (2000) reported that the total sugar content in young garlic leaves ranged from 19.68 - 22.04%. Mahajan *et al*. (2011) discovered that garlic had a higher total sugar content (198.8 mg/g fresh weight) than onion types (78.4 mg/g fresh weight). Kolota *et al*. (2013) reported 4.11% f.m. of total sugars in Japanese bunching onion.

Different growing conditions

According to Kolota *et al.* (2013), covering plants of japanese bunching onion with a perforated foil positively influenced the content of total sugars as compared to those cultivated without covers.

4.2.4.5 Reducing sugar (%)

The amount of reducing sugar in *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.16. It ranged between 13.84 percent and 19.16 percent.

The data shows that *Allium tuberosum* had significantly highest amount of reducing sugar (14.14 percent) under open condition and the lowest amount of reducing sugar (13.84 percent) when grown in a rain shelter. *Allium chinense* had significantly highest amount of reducing sugar (19.16 percent) under open condition and the lowest amount of reducing sugar (17.72 percent) when grown in a rain shelter.

Thus, based on our observations we can conclude that both the species had highest amount of reducing sugar in open condition (*A. tuberosum* – 14.14 percent and *A. chinense* – 19.16 percent) and least amount of reducing sugar when grown in rain shelter (*A. tuberosum* – 13.84 percent and *A. chinense* – 17.72 percent).

When comparing the two species, *A. chinense* had highest quantity of reducing sugar than *A. tuberosum*. The quantity of reducing sugar in the plants differed significantly depending on the species and the growing conditions.

The findings of Mahajan *et al*. (2011) are similar to those of the current investigation. According to Masoodi *et al*., 2020 reducing sugar is essential for deciding the quality and appearance of processed onion. Glucose, galactose, lactose, maltose, and fructose are examples of reducing sugars. Adamczewka *et al*. (2016) reported that *Allium tuberosum* leaves comprised 11.37 g/kg of reducing sugar. Reducing sugars in onion ranged from 2.26 percent to 3.79 percent, according to Masoodi *et al*. (2020).

4.2.4.6 Non reducing sugar (%)

The amount of non-reducing sugar in *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.16. It ranged between 5.76 and 9.33 percent. The quantity of non-reducing sugar in the plants differed significantly depending on the species and the growing conditions.

Data indicates that *Allium tuberosum* had significantly highest quantity of non-reducing sugar (6.8 percent) in open condition and the lowest quantity of non-reducing sugar (5.76 percent) when grown under rain shelter. *Allium chinense* had significantly highest quantity of non-reducing sugar (9.33 percent) under open condition and the lowest quantity of non-reducing sugar (8.33 percent) when grown under rain shelter.

Thus, based on our observations we can conclude that both the species had highest amount of non-reducing sugar in open condition (*A. tuberosum* – 6.8

percent and *A. chinense* – 9.33 percent) and least amount of non-reducing sugar when grown in rain shelter (*A. tuberosum* – 5.76 percent and *A. chinense* – 8.33 percent).

When comparing the two species, *A. chinense* has highest quantity of non-reducing sugar than *A. tuberosum*. The quantity of non-reducing sugar in the plants differed significantly depending on the species and the growing conditions.

According to Masoodi *et al*. (2020), non-reducing sugars in onions ranged from 2.97 percent to 4.29 percent.

4.2.4.7 Sulphur content (%)

Sulphur content of *Allium* species grown under different growing conditions under study is presented in Table 4.8 and Fig- 4.17. It ranged between 0.8 and 0.97 %.

It reveals that *Allium tuberosum* had significantly highest sulphur content (0.97 percent) under open condition and the lowest sulphur content (0.95 percent) when grown in rain shelter. *Allium chinense* had significantly highest sulphur content (0.85 percent) under open condition and the lowest sulphur content (0.8 percent) when grown in a rain shelter.

From the results, we can infer that sulphur content was highest in both species cultivated in open condition (*A. tuberosum* – 0.97 percent and *A. chinense* – 0.85 percent), and lowest under rain shelter (*A. tuberosum* – 0.95 percent and *A. chinense* – 0.8 percent). When comparing the two species, *A. tuberosum* has highest sulphur content than *A. chinense*. It shows that the sulphur content in the plants differed significantly depending on the species and the growing conditions.

Alliums have a pungent taste that comes from a variety of volatile sulphur compounds. When a cell is physically damaged, the enzyme alliinase comes into touch with flavour precursors such S-alk(en)yl-L-cysteine sulfoxides (ACSOs), resulting in the formation of these compounds. One of the most important elements in plants is sulphur. Allyl propyl disulphide, a sulphur molecule, may enhance insulin production and reduce blood glucose levels. Sulphur has a significant impact on the quality and torability of food (Tondon and Messick, 2002). Sulphur is a component of secondary metabolite compounds, which include a variety of volatile precursors that are essential in determining the quality of product (Smittle, 1984).

In the present study both the species of *Allium* possessed appreciable quantity of sulphur in their leaves and its content appeared to be high under open condition. This could be an indication of the quality of the leaves.

4.2.5 Storage study

The purpose of this study was to look at the various storage systems and packaging materials used in *Allium tuberosum* and *Allium chinense* leaves. The storage research examines physical parameter such as physiological weight loss and organoleptic evaluation, which includes a score for colour, appearance, texture, taste, and aroma based on a 9-point Hedonic scale developed by Amerine *et al*. (1965).

4.2.5.1 Physiological loss of weight (%)

a) A. tuberosum

Table 4.9 depicts, the effect of different treatment combinations of packaging material types and varied storage conditions on physiological loss of weight of *Allium tuberosum* leaves enhanced as the storage time was prolonged. At the end of the second day of storage, treatment T_3P_4 had the highest physiological loss of weight (20.8%), followed by T_3P_3 (18.16%). T_1P_2 had the lowest physiological loss of weight (2.2%), closely followed by T_1P_1 (2.4 percent). On the fourth day of

Table 4.9: Effect of storage methods and packaging materials on physiological loss in weight (PLW) of leaves in *A. tuberosum*

Treatment combinations	Physiological loss of weight (%)					
	Storage period in days					
	2	4	6	8	10	12
T_1P_1	2.4	3.46	5.96	7.9	11.05	12.73
T_1P_2	2.2	3.26	4.53	5.5	7.8	9.85
T_1P_3	9.76	12.46	15	25.46	32.66	34.86
T_1P_4	12.66	16.2	24.66	28.5	36.26	42.72
T_2P_1	3	8.33	10.66	11.36	12.03	17.45
T_2P_2	2.33	6.66	10	10.3	10.8	15.45
T_2P_3	3	12.36	18	26.03	35.4	38.15
T_2P_4	4.33	14.76	18.9	27.1	34.13	42.01
T_3P_1	5.66	18.9	-	-	-	-
T_3P_2	4.83	18.6	-	-	-	-
T_3P_3	18.16	59.16	-	-	-	-
T_3P_4	20.8	65.3	-	-	-	-
CD (5%)	**2.296**	**3.714**	**3.954**	**2.858**	**1.113**	**2.332**
SE (d)	**1.106**	**1.789**	**1.849**	**1.337**	**0.521**	**1.091**
C.V (5%)	**18.228**	**10.976**	**16.82**	**9.212**	**2.831**	**5.011**

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

storage, T_3P_4 had the highest physiological loss of weight (65.3%), followed by T_3P_3 (59.16%). T_1P_2 had the lowest physiological loss of weight (3.26%), closely followed by T_1P_1 (3.46%). On the sixth day of storage, leaves in open condition were damaged in all the packaging materials and only refrigerated and cold storage samples were available for observation, and T_1P_4 had the highest physiological loss of weight (24.66%), followed by T_2P_3 (18.9%), and lowest physiological loss of weight was recorded by T_1P_2 (4.53 percent) which was closely followed by T_1P_1

(5.96 percent). On the eighth day of storage, T_1P_4 recorded the highest physiological loss of weight (28.5%), followed by T_2P_4 (27.1%), and T_1P_2 had the lowest physiological loss of weight (5.5%), closely followed by T_1P_1 (7.9 percent). On the tenth day of storage, T_1P_4 had the highest physiological loss of weight (36.26%), followed by T_2P_3 (35.4%), and T_1P_2 had the lowest physiological loss of weight (7.8%), closely followed by T_1P_1 (11.05 percent). T_1P_4 recorded the highest physiological loss of weight (36.26 percent) on the 12th day of storage, followed by T_2P_3 (35.4 percent), and T_1P_2 recorded the lowest physiological loss of weight (7.8%), closely followed by T_1P_1 (11.05 percent).

The leaves of *Allium tuberosum* stored in ambient conditions lost the most PLW compared to those held in cold storage and refrigerated conditions. The leaves of *Allium tuberosum* packed in 200-gauge LDPE with perforation recorded lowest PLW followed by 200-gauge LDPE and it was recorded highest in tissue paper wrapping followed by brown paper bag in all the storage conditions. Chauhan (1981); Waskar *et al*. (1999) in bottle gourd fruits; Negi and Roy (2003) in amaranth and fenugreek leaves reported comparable results. Throughout the storage time, regardless of storage temperatures, a trend of increased PLW was observed. 200-gauge LDPE with perforation in refrigerated storage had the lowest PLW since it had the highest humidity and the lowest temperature. Weight loss is a critical component since it is linked to economic challenges, and weight loss of more than 5-10% lowers the market value of leafy vegetables (Brown and Bourne, 2002). According to Ben-Yehoshua (1987), weight loss in leafy vegetables is determined by a number of factors, the most important of which is the resistance exerted by the outer periderm or cuticle to the movement of water vapour owing to transpiration. According to Thompson (2004), temperature and relative humidity must be managed to prevent vegetable moisture loss. Under varied storage circumstances, the current findings are comparable to those of Sharangi (2015) in coriander, Kulkarni (2015) in fenugreek and spinach, Indore (2016) in okra and Ambuko *et al*. (2017) in leafy amaranthus.

b) A. chinense

Table 4.10: Effect of storage methods and packaging materials on physiological loss in weight (PLW) of leaves in *A. chinense*

Treatment combinations	Physiological loss of weight (%)					
	Storage period in days					
	2	**4**	**6**	**8**	**10**	**12**
T_1P_1	1.06	1.98	4	6.55	8.82	10.92
T_1P_2	1.05	1.8	3.3	4.5	5.37	7
T_1P_3	7	10.3	14	20.32	27.65	35.5
T_1P_4	9.5	12.16	15	22.5	30.5	40.92
T_2P_1	5	6.51	8.01	9.8	11.92	13.02
T_2P_2	4.5	6.3	7.65	9.69	10.68	11.92
T_2P_3	9.66	17.3	21.95	25.85	34.55	36.8
T_2P_4	12	18.02	23.15	28.45	34.5	41.22
T_3P_1	5.96	17.5	40	-	-	-
T_3P_2	5.53	14.8	35	-	-	-
T_3P_3	13.53	29.55	58	-	-	-
T_3P_4	16.66	44.05	66	-	-	-
CD (5%)	**1.2**	**1.254**	**1.65**	**1.683**	**1.69**	**1.748**
SE (d)	**0.58**	**0.604**	**0.772**	**0.787**	**0.791**	**0.818**
C.V (5%)	**9.315**	**4.924**	**7.788**	**6.039**	**4.724**	**4.06**

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

As shown in Table 4.10, the effect of different treatment combinations of packaging material types and varied storage conditions on physiological loss of weight was found to be enhanced as the storage term was prolonged. At the end of the second day of storage, treatment T_3P_4 had the highest physiological loss of weight (16.66%), followed by T_3P_3 (13.53%), and T_1P_2 had the lowest physiological loss of weight (1.05%), closely followed by T_1P_1 (1.06 percent). On the fourth day of storage, T_3P_4 had the highest physiological loss of weight (44.05%), followed by T_3P_3 (29.55%), and T_1P_2 had the lowest physiological loss of weight (1.8%), closely followed by T_1P_1 (1.98%). On the sixth day of storage,

T_3P_4 had the highest physiological loss of weight (66), followed by T_3P_3 (58%), and T_1P_2 had the lowest physiological loss of weight (3.3%), closely followed by T_1P_1 (4%). On the eighth day of storage, leaves in open condition were damaged in all the packaging materials and only refrigerated and cold storage samples were available for observation, and T_2P_4 had the highest physiological loss of weight (28.45%), followed by T_2P_3 (25.85%), and lowest physiological loss of weight was recorded by T_1P_2 (4.5 percent) which was closely followed by T_1P_1 (6.55 percent). On the tenth day of storage, T_2P_3 had the most physiological loss of weight (34.55%), followed by T_2P_4 (34.5%), and T_1P_2 had the lowest physiological loss of weight (5.37%), closely followed by T_1P_1 (8.82 percent). T_2P_4 had the most physiological loss of weight (41.22 percent) on the 12th day of storage, followed by T_2P_3 (36.8 percent), and T_1P_2 had the lowest physiological loss of weight observed in T_1P_2(7%), closely followed by T_1P_1 (10.92 percent).

The leaves of *Allium chinense* stored in ambient conditions lost the most PLW compared to those held in cold storage and refrigerated conditions. The leaves of *Allium chinense* packed in 200-gauge LDPE with perforation recorded lowest PLW followed by 200-gauge LDPE and it was recorded highest in tissue paper wrapping followed by brown paper bag in all the storage conditions. Chauhan (1981); Waskar *et al*. (1999) in bottle gourd fruits; Negi and Roy (2004) in amaranth and fenugreek leaves reported comparable results. Throughout the storage time, regardless of storage temperatures, a trend of increased PLW was observed. Refrigerated storage had the lowest PLW since it had the highest humidity and the lowest temperature. Weight loss is a critical component since it is linked to economic challenges, and weight loss of more than 5-10% lowers the market value of leafy vegetables (Brown and Bourne, 2002). According to Ben-Yehoshua (1987), weight loss in leafy vegetables is determined by a number of factors, the most important of which is the resistance exerted by the outer periderm or cuticle to the movement of water vapour owing to transpiration. According to Thompson (2004), temperature and relative humidity must be managed to prevent vegetable moisture loss. Under varied storage circumstances, the current findings are comparable to those of Sharangi (2015) in coriander, Kulkarni (2015) in fenugreek and spinach, Indore (2016) in okra and Ambuko *et al*. (2017) in leafy amaranthus.

4.2.5.2 Organoleptic evaluation

a. Appearance

Table 4.11: Effect of storage methods and packaging materials on organoleptic score for appearance of leaves in *A. tuberosum*

Treatment combinations	Score for appearance						
	Storage period in days						
	0	2	4	6	8	10	12
T_1P_1	9	8.7	8.2	8	7	6.6	5.4
T_1P_2	9	8.8	8.5	8.16	7.2	6.8	5.7
T_1P_3	9	8.1	7.5	7	6.5	6.2	5
T_1P_4	9	8.1	7.5	6.8	6.3	6	4.75
T_2P_1	9	7.8	7	6.5	6.3	5.5	4.5
T_2P_2	9	7.8	7.2	7	6.5	5.8	4.8
T_2P_3	9	7.5	6.5	6.3	5.8	5.2	4.3
T_2P_4	9	7	6.4	6	5.5	5	4
T_3P_1	9	4.6	3	-	-	-	-
T_3P_2	9	4.8	4	-	-	-	-
T_3P_3	9	5.2	3	-	-	-	-
T_3P_4	9	5	3	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for appearance of leaves in *A. tuberosum* have been presented in Table 4.11. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.8) whereas lowest score was recorded in T_3P_1 (4.6) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (8.5) whereas lowest score was recorded in T_3P_1(3), T_3P_3 (3) and T_3P_4 (3). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (8.16), and lowest in T_2P_4 (6). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (7.2), and lowest in T_2P_4 (5.5). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.8), and lowest in T_2P_4 (5). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.7), and lowest in T_2P_4 (4). The leaves of *Allium tuberosum* stored in ambient conditions lowest score for appearance compared to those held in cold storage and refrigerated conditions. The leaves of *Allium tuberosum* packed in 200-gauge LDPE with perforation recorded highest score for appearance followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions. The results of present findings are in concurs with earlier research work reported by Narang *et al*. (2016) in fenugreek and Patil (2016) in lettuce.

Table 4.12: Effect of storage methods and packaging materials on organoleptic score for appearance of leaves in *A. chinense*

Treatment	Score for appearance						
	Storage period in days						
	0	2	4	6	8	10	12
T_1P_1	9	8.8	8.3	8	7.2	6.7	5.6
T_1P_2	9	8.9	8.5	8.2	7.5	6.85	5.8
T_1P_3	9	8.4	7.7	7.4	6.5	6.5	5.5
T_1P_4	9	8.2	7.6	7.2	6.4	6	5
T_2P_1	9	7.8	7.2	6.8	6.5	5.6	4.8
T_2P_2	9	8	7.4	7	6.6	5.85	5
T_2P_3	9	7.58	6.8	6.5	6	5.3	4.5
T_2P_4	9	7.4	6.5	6.15	5.7	5.16	4.2
T_3P_1	9	4.7	3.5	-	-	-	-
T_3P_2	9	4.9	4.5	-	-	-	-
T_3P_3	9	5.3	4	-	-	-	-
T_3P_4	9	5.1	4	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for appearance of leaves in *A. chinense* have been presented in Table 4.12. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.9) whereas lowest score was recorded in T_3P_1 (4.7) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (8.5) whereas lowest score was recorded in T_3P_1(3.5). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (8.2), and lowest in T_2P_4 (6.15). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (7.5), and lowest in T_2P_4 (5.7). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.85), and lowest in T_2P_4 (5.16). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.8), and lowest in T_2P_4 (4.2). The leaves of *Allium chinense* stored in ambient conditions lowest score for appearance compared to those held in cold storage and refrigerated conditions. The leaves of *Allium chinense* packed in 200-gauge LDPE with perforation recorded highest score for appearance followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions. The results of present findings are in concurs with earlier research work reported by Narang *et al*. (2016) in fenugreek and Patil (2016) in lettuce.

b) Colour

The data with respect to effects of methods and packaging materials on score for colour of leaves in *A. tuberosum* have been presented in Table 4.13. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.85) whereas lowest score was recorded in T_3P_1 (5) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.66) whereas lowest score was recorded in T_3P_1(3.5). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.15), and lowest in T_2P_4 (6.2). On 8th day of storage, the score for appearance was found to be

Table 4.13: Effect of storage methods and packaging materials on organoleptic score for colour of leaves in *A. tuberosum*

Treatment	Score for colour						
	Storage period in days						
	0	2	4	6	8	10	12
T_1P_1	9	8.5	7.45	7	6.62	6	5.35
T_1P_2	9	8.85	7.66	7.15	6.7	6.2	5.5
T_1P_3	9	8.4	7.5	6.8	6	5.64	5
T_1P_4	9	8.3	7.4	6.7	5.8	5.41	4.8
T_2P_1	9	7.45	7	6.35	5.85	5.2	4
T_2P_2	9	7.55	7.2	6.5	6	5.35	4.12
T_2P_3	9	7.2	6.8	6.3	5.62	4.85	3.7
T_2P_4	9	7	6.5	6.2	5.4	4.68	3.51
T_3P_1	9	5	3.5	-	-	-	-
T_3P_2	9	5.5	3.8	-	-	-	-
T_3P_3	9	5.6	4.8	-	-	-	-
T_3P_4	9	5.65	4	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

highest in T_1P_2 (6.7), and lowest in T_2P_4 (5.4). On 10^{th} day of storage, the score for appearance was found be highest in T1P2 (6.2), and lowest in T_2P_4 (4.68). On 12^{th} day of storage, the score for appearance was found be highest in T_1P_2 (5.5), and lowest in T_2P_4 (3.51). The leaves of *Allium tuberosum* stored in ambient conditions lowest score for colour compared to those held in cold storage and refrigerated conditions. The leaves of *Allium tuberosum* packed in 200-gauge LDPE with perforation recorded highest score for colour followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions.

Similar findings were reported by Sharangi *et al*. (2015) in coriander, Indore (2016) in okra, and Patil (2016) in lettuce, all of whom indicated that vegetables with high total chlorophyll content had the best colour scores. Colour variations degrade the quality and market demand of the leaves, which is more common with ambient temperature storage and packing materials. Colour showed a downward tendency throughout the storage time, regardless of the storage types.

Table 4.14: Effect of storage methods and packaging materials on organoleptic score for colour of leaves in *A. chinense*

Treatment	**Score for colour**						
	Storage period in days						
	0	**2**	**4**	**6**	**8**	**10**	**12**
T_1P_1	9	8.53	7.48	7	6.72	6	5.4
T_1P_2	9	8.82	7.67	7.35	6.8	6.32	5.62
T_1P_3	9	8.45	7.51	6.7	6.13	5.69	5.19
T_1P_4	9	8.32	7.4	6.6	5.8	5.45	4.82
T_2P_1	9	7.45	7.03	6.35	5.75	5.24	4
T_2P_2	9	7.55	7.21	6.5	6	5.35	4.15
T_2P_3	9	7.21	6.83	6.15	5.72	4.67	3.68
T_2P_4	9	7.18	6.52	6	5.48	4.4	3.47
T_3P_1	9	5	3.6	-	-	-	-
T_3P_2	9	5.5	3.9	-	-	-	-
T_3P_3	9	5.6	4.8	-	-	-	-
T_3P_4	9	5.65	4.5	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for colour of leaves in *A. chinense* have been presented in Table 4.14. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.82) whereas lowest score was recorded in T_3P_1 (5) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.67) whereas lowest score was recorded in T_3P_1(3.6). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.35), and lowest in T_2P_4 (6). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.8), and lowest in T_2P_4 (5.48). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.32), and lowest in T_2P_4 (4.4). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.62), and lowest in T_2P_4 (3.47). The leaves of *Allium chinense* stored in ambient conditions lowest score for colour compared to those held in cold storage and refrigerated conditions. The leaves of *Allium chinense* packed in 200-gauge LDPE with perforation recorded highest score for colour followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions.

Similar findings were reported by Sharangi *et al*. (2015) in coriander, Indore (2016) in okra, and Patil (2016) in lettuce, all of whom indicated that vegetables with high total chlorophyll content had the best colour scores. Colour variations degrade the quality and market demand of the leaves, which is more common with ambient temperature storage and packing materials. Colour showed a downward tendency throughout the storage time, regardless of the storage types.

c) Texture

The data with respect to effects of methods and packaging materials on score for texture of leaves in *A. tuberosum* have been presented in Table 4.15. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.6) whereas lowest score was recorded in T_3P_1 (4.9) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.5) whereas lowest score was recorded in T_3P_1(3.4). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.19), and lowest in T_2P_4 (5.8). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.77), and lowest in T_2P_4 (5.39). On 10th day of storage, the score for

Table 4.15: Effect of storage methods and packaging materials on organoleptic score for texture of leaves in *A. tuberosum*

Treatment	Score for texture						
	Storage period in days						
	0	2	4	6	8	10	12
T_1P_1	9	8.42	7.32	6.85	6.56	5.95	5.2
T_1P_2	9	8.6	7.5	7.19	6.77	6.18	5.48
T_1P_3	9	8.3	7.25	6.58	6	5.47	4.95
T_1P_4	9	8.15	7.18	6.45	5.68	5.4	4
T_2P_1	9	7.45	7	6.2	5.56	5.2	3.85
T_2P_2	9	7.68	7.25	6.4	6	5.4	4
T_2P_3	9	7.35	6.69	6	5.58	4.5	3.4
T_2P_4	9	7.2	6.4	5.8	5.39	4.2	3.3
T_3P_1	9	4.9	3.4	-	-	-	-
T_3P_2	9	5	3.68	-	-	-	-
T_3P_3	9	5.2	4.55	-	-	-	-
T_3P_4	9	5.45	4.4	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

appearance was found be highest in T_1P_2 (6.18), and lowest in T_2P_4 (4.2). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.48), and lowest in T_2P_4 (3.3). The leaves of *Allium tuberosum* stored in ambient conditions lowest score for texture compared to those held in cold storage and refrigerated conditions. The leaves of *Allium tuberosum* packed in 200-gauge LDPE with perforation recorded highest score for texture followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions.

The texture of the leaves scored lower at room temperature and steadily improved in the cold chamber and in the refrigerated condition. The fast loss of texture of leaves attributable to their exposure to atmospheric gases with the consequent fading away of their greenish texture was observed by Brar *et al*., (2013) in fenugreek, and similar results were reported by Komolafe and Idah (2008) and Indore (2016) in okra.

Table 4.16: Effect of storage methods and packaging materials on organoleptic score for texture of leaves in *A. chinense*

Treatment	Score for texture						
	Storage period in days						
	0	2	4	6	8	10	12
T_1P_1	9	8.5	7.4	6.9	6.6	6	5.25
T_1P_2	9	8.71	7.6	7.2	6.8	6.2	5.5
T_1P_3	9	8.38	7.35	6.6	6.05	5.5	5
T_1P_4	9	8.2	7.2	6.5	5.7	5.42	4
T_2P_1	9	7.5	7	6.25	5.65	5.25	3.9
T_2P_2	9	7.72	7.21	6.45	6	5.34	4.03
T_2P_3	9	7.37	6.7	6.1	5.6	4.6	3.5
T_2P_4	9	7.22	6.42	5.9	5.4	4.3	3.35
T_3P_1	9	4.8	3.44	-	-	-	-
T_3P_2	9	5	3.7	-	-	-	-
T_3P_3	9	5.3	4.6	-	-	-	-
T_3P_4	9	5.5	4.42	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for texture of leaves in *A. chinense* have been presented in Table 4.16. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.71) whereas lowest score was recorded in T_3P_1 (4.8) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.6) whereas lowest score was recorded in T_3P_1(3.44). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.2), and lowest in T_2P_4 (5.9). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.8), and lowest in T_2P_4 (5.4). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.2), and lowest in T_2P_4 (4.3). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.5), and lowest in T_2P_4 (3.35). The leaves stored in ambient conditions lowest score for texture compared to those held in cold storage and refrigerated conditions. The leaves packed in 200-gauge LDPE with perforation recorded highest score for texture followed by 200-gauge LDPE and it was recorded lowest in tissue paper wrapping followed by brown paper bag in all the storage conditions.

The texture of the leaves scored lower at room temperature and steadily improved in the cold chamber and in the refrigerated condition. The fast loss of texture of leaves attributable to their exposure to atmospheric gases with the consequent fading away of their greenish texture was observed by Brar *et al*., (2013) in fenugreek, and similar results were reported by Komolafe and Idah (2008) and Indore (2016) in okra.

d) Odour

Table 4.17: Effect of storage methods and packaging materials on organoleptic score for odour of leaves in *A. tuberosum*

Treatment	Score for odour						
	Storage period in days						
	0	**2**	**4**	**6**	**8**	**10**	**12**
T_1P_1	9	8	7.5	7	6.5	6	5.5
T_1P_2	9	8.18	7.6	7.2	6.7	6.2	5.68
T_1P_3	9	7.8	7.4	6.8	5.9	5.5	5
T_1P_4	9	7.6	7.3	6.58	5.7	5.36	4.45
T_2P_1	9	7.1	7	6.25	5.5	5.17	3.8
T_2P_2	9	7.48	7.17	6.5	5.7	5.28	4
T_2P_3	9	7	6.68	5.9	5.45	4.5	3.55
T_2P_4	9	6.9	6.46	5.7	5.38	4.35	3.4
T_3P_1	9	5	3.3	-	-	-	-
T_3P_2	9	5.28	3.5	-	-	-	-
T_3P_3	9	5.35	3.85	-	-	-	-
T_3P_4	9	5.2	4	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃
T_2: Cold storage: 12-13℃
T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE
P_2: 200-gauge LDPE with perforation
P_3: Brown paper bag
P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for odour of leaves in *A. tuberosum* have been presented in Table 4.17. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.18) whereas lowest score was recorded in T_3P_1 (5) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.6) whereas lowest score was recorded in T_3P_1(3.3). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.2), and lowest in T_2P_4 (5.7). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.7), and lowest in T_2P_4 (5.38). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.2), and lowest in T_2P_4 (4.35). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.68), and lowest in T_2P_4 (3.4).

Throughout the storage period, a declining trend in the score for odour was seen in all treatments. The odour faded off faster at ambient temperature than in the cold chamber or the refrigerated conditions. The refrigerated condition received the highest grade for odour and had a higher commercial acceptability than the ambient and cold storage conditions. The humidity and temperature in the refrigerated state were the highest and lowest, respectively, preserving the odour of the produce for longer.

Brar *et al*., (2013) reported similar results with fenugreek, claiming that perforations prevented the build-up of O_2 and CO_2, resulting in greater odour retention.

Table 4.18: Effect of storage methods and packaging materials on organoleptic score for odour of leaves in *A. chinense*

Treatment	Score for odour						
	Storage period in days						
	0	**2**	**4**	**6**	**8**	**10**	**12**
T_1P_1	9	8	7.5	7	6.5	6	5.5
T_1P_2	9	8.2	7.69	7.25	6.75	6.26	5.7
T_1P_3	9	7.85	7.45	7	6	5.6	5
T_1P_4	9	7.62	7.38	6.7	5.75	5.4	4.5
T_2P_1	9	7.2	7.15	6.3	5.6	5.2	3.9
T_2P_2	9	7.5	7.2	6.52	5.8	5.3	4.12
T_2P_3	9	7.1	6.7	6	5.5	4.6	3.6
T_2P_4	9	7	6.5	5.8	5.4	4.4	3.42
T_3P_1	9	5.17	3.4	-	-	-	-
T_3P_2	9	5.3	3.6	-	-	-	-
T_3P_3	9	5.4	4	-	-	-	-
T_3P_4	9	5.35	4.2	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for odour of leaves in *A. chinense* have been presented in Table 4.18. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.2) whereas lowest score was recorded in T_3P_1 (5.17) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.69) whereas lowest score was recorded in T_3P_1(3.4). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.25), and lowest in T_2P_4 (5.8). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.75), and lowest in T_2P_4 (5.4). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.26), and lowest in T_2P_4 (4.4). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.7), and lowest in T_2P_4 (3.42).

Throughout the storage period, a declining trend in the score for odour was seen in all treatments. The odour faded off faster at ambient temperature than in the cold chamber or the refrigerated conditions. The refrigerated condition received the highest grade for odour and had a higher commercial acceptability than the ambient and cold storage conditions. The humidity and temperature in the refrigerated state were the highest and lowest, respectively, preserving the odour of the produce for longer.

Brar *et al*., (2013) reported similar results with fenugreek, claiming that perforations prevented the build-up of O_2 and CO_2, resulting in greater odour retention.

e) Overall acceptability

The overall acceptability of leaves was calculated using the scores obtained from the other sensory characteristics used to evaluate appearance, colour, texture, and odour, as shown in Tables 4.19 and 4.20. The overall acceptability of leaves declined as the storage duration progressed, regardless of storage type.

Table 4.19: Effect of storage methods and packaging materials on organoleptic score for overall acceptability of leaves in *A. tuberosum*

Treatment	Score for overall acceptability						
	Storage period in days						
	0	**2**	**4**	**6**	**8**	**10**	**12**
T_1P_1	9	8.41	7.62	7.21	6.67	6.14	5.36
T_1P_2	9	8.61	7.82	7.43	6.84	6.35	5.59
T_1P_3	9	8.15	7.41	6.80	6.10	5.70	4.99
T_1P_4	9	8.04	7.35	6.63	5.87	5.54	4.50
T_2P_1	9	7.45	7.00	6.33	5.80	5.27	4.04
T_2P_2	9	7.63	7.21	6.60	6.05	5.46	4.23
T_2P_3	9	7.26	6.67	6.13	5.61	4.76	3.74
T_2P_4	9	7.03	6.44	5.93	5.42	4.56	3.55
T_3P_1	9	4.88	3.30	-	-	-	-
T_3P_2	9	5.15	3.75	-	-	-	-
T_3P_3	9	5.34	4.05	-	-	-	-
T_3P_4	9	5.33	3.85	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for overall acceptability of leaves in *A. tuberosum* have been presented in Table 4.19. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.61) whereas lowest score was recorded in T_3P_1 (4.88) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.82) whereas lowest score was recorded in T_3P_1(3.3). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.43), and lowest in T_2P_4 (5.93). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.84), and lowest in T_2P_4 (5.42). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.35), and lowest in T_2P_4 (4.56). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.59), and lowest in T_2P_4 (3.55).

Table 4.20: Effect of storage methods and packaging materials on organoleptic score for overall acceptability of leaves in *A. chinense*

Treatment	Score for overall acceptability						
	Storage period in days						
	0	**2**	**4**	**6**	**8**	**10**	**12**
T_1P_1	9	8.46	7.67	7.23	6.76	6.18	5.44
T_1P_2	9	8.66	7.87	7.50	6.96	6.41	5.66
T_1P_3	9	8.27	7.50	6.93	6.17	5.82	5.17
T_1P_4	9	8.09	7.40	6.75	5.91	5.57	4.58
T_2P_1	9	7.49	7.10	6.43	5.88	5.32	4.15
T_2P_2	9	7.69	7.26	6.62	6.10	5.46	4.33
T_2P_3	9	7.32	6.76	6.19	5.71	4.79	3.82
T_2P_4	9	7.20	6.49	5.96	5.50	4.57	3.61
T_3P_1	9	4.92	3.49	-	-	-	-
T_3P_2	9	5.18	3.93	-	-	-	-
T_3P_3	9	5.40	4.35	-	-	-	-
T_3P_4	9	5.40	4.28	-	-	-	-

'-' Indicates termination of treatment

T_1: Refrigeration: 5-7℃

T_2: Cold storage: 12-13℃

T_3: Ambient conditions: 30-35℃

P_1: 200-gauge LDPE

P_2: 200-gauge LDPE with perforation

P_3: Brown paper bag

P_4: Tissue paper wrapping

The data with respect to effects of storage methods and packaging materials on score for overall acceptability of leaves in *A. chinense* have been presented in Table 4.20. The data revealed that, highest score for appearance was recorded by the treatment combination of T_1P_2 (8.66) whereas lowest score was recorded in T_3P_1 (4.92) on 2nd day of storage. On 4th day of storage, the score for appearance was found to be highest in T_1P_2 (7.87) whereas lowest score was recorded in T_3P_1(3.49). On 6th day of storage, the score for appearance was found be highest in T_1P_2 (7.5), and lowest in T_2P_4 (5.96). On 8th day of storage, the score for appearance was found be highest in T_1P_2 (6.96), and lowest in T_2P_4 (5.5). On 10th day of storage, the score for appearance was found be highest in T_1P_2 (6.41), and lowest in T_2P_4 (4.57). On 12th day of storage, the score for appearance was found be highest in T_1P_2 (5.66), and lowest in T_2P_4 (3.61).

Furthermore, refrigerated storage was found to be effective in maintaining the appearance, colour, texture, odour, and overall acceptability throughout the storage period; this could be due to the low temperature during storage, which resulted in reduced minimum moisture and physiological weight loss. The outcomes of this study are consistent with those published by Kim *et al*. (2014) in salad savoy, Indore (2016) in okra and Jha and Matsuoka (2005) in tomato.

The results shows that there was a significant effect of storage conditions and packaging materials on physiological loss of weight and organoleptic quality of *Allium* leaves during storage period.

Fig- 4.18: Effect of storage methods and packaging materials on cumulative PLW (%) of leaves in *A. tuberosum*

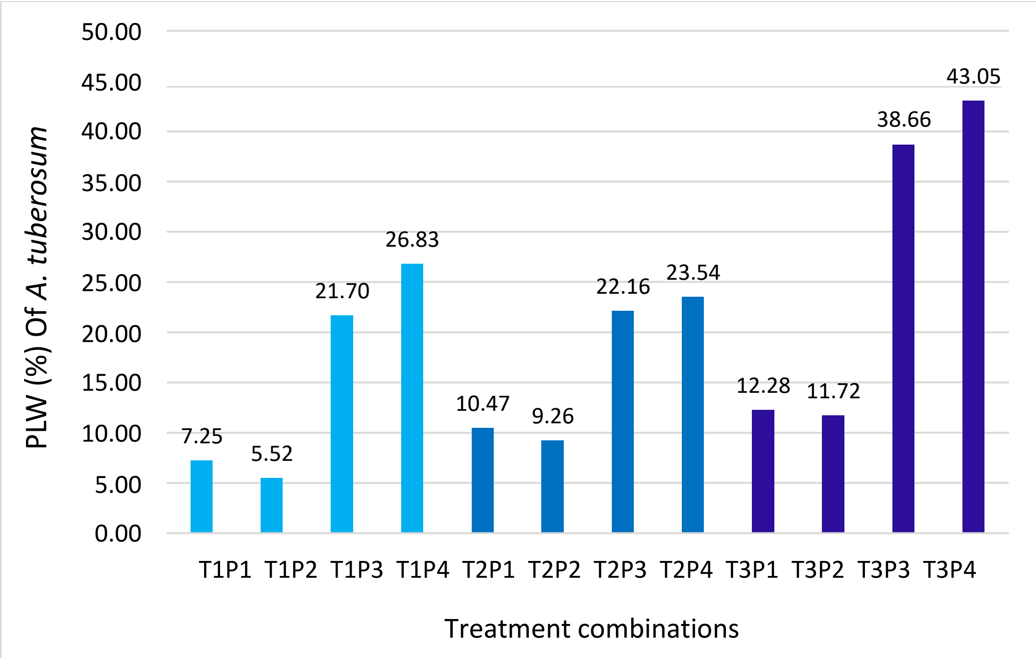


Fig- 4.19: Effect of storage methods and packaging materials on cumulative PLW (%) of leaves in *A. chinense*

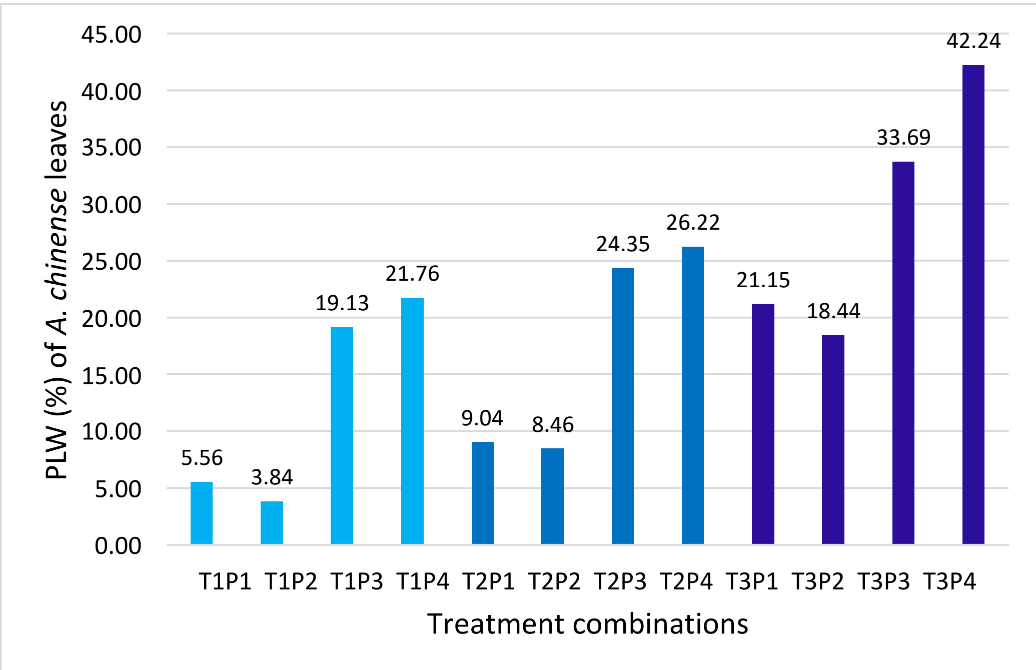


Fig- 4.20: Effect of storage methods and packaging materials on cumulative organoleptic score for appearance of leaves in *A. tuberosum*

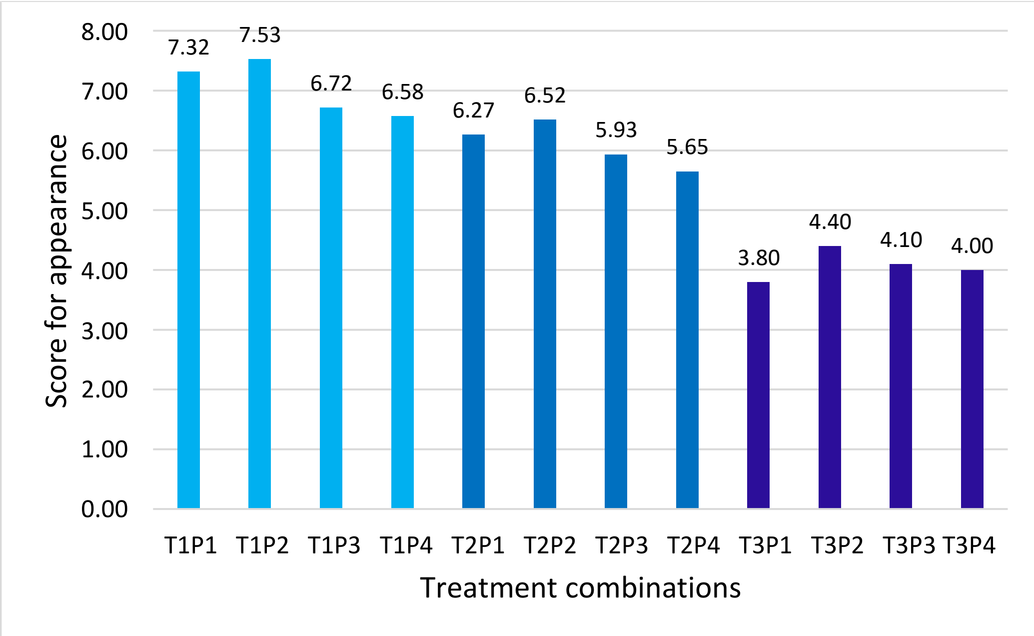


Fig- 4.21: Effect of storage methods and packaging materials on cumulative organoleptic score for appearance of leaves in *A. chinense*

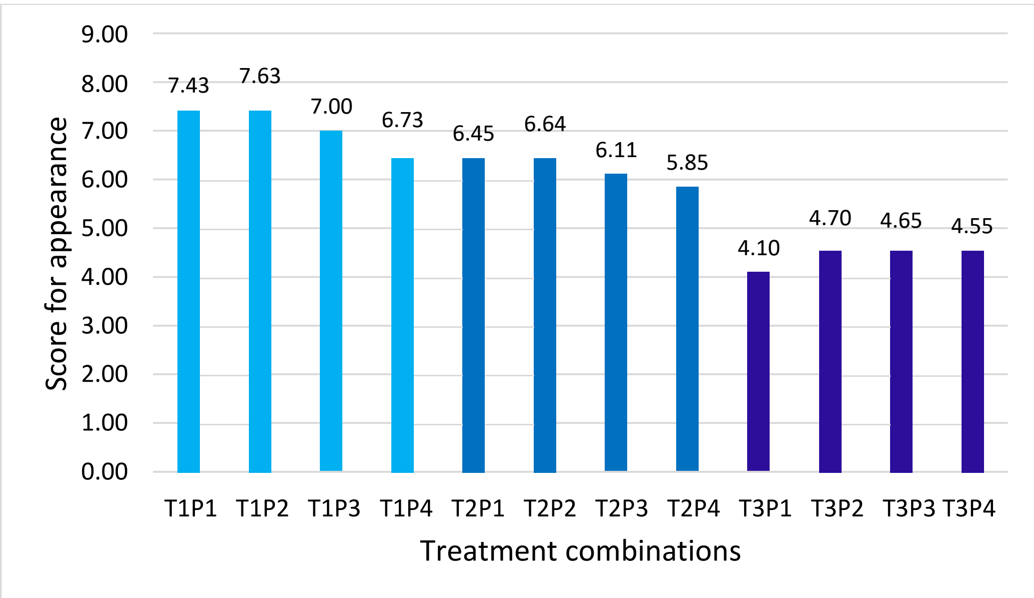


Fig- 4.22: Effect of storage methods and packaging materials on cumulative organoleptic score for colour of leaves in *A. tuberosum*

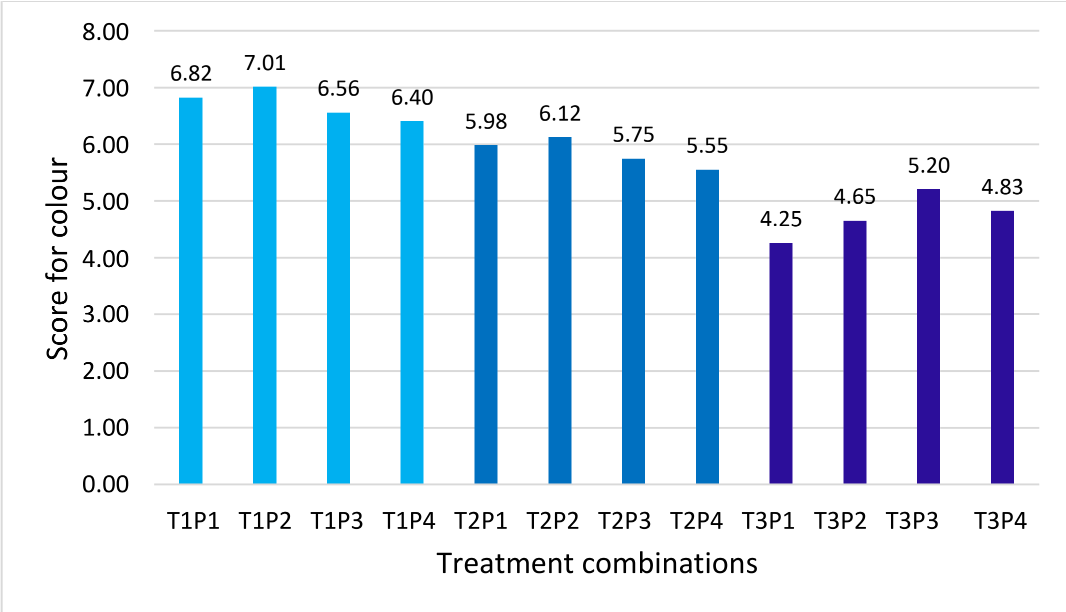


Fig- 4.23: Effect of storage methods and packaging materials on cumulative organoleptic score for colour of leaves in *A. chinense*

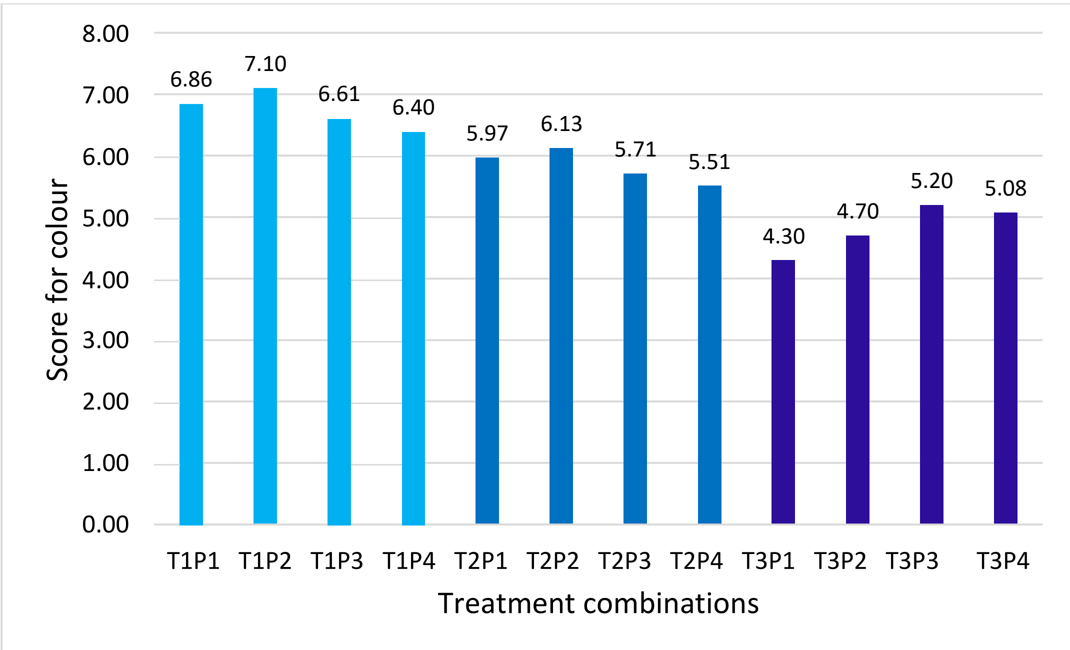


Fig-4.24: Effect of storage methods and packaging materials on cumulative organoleptic score for texture of leaves in *A. tuberosum*

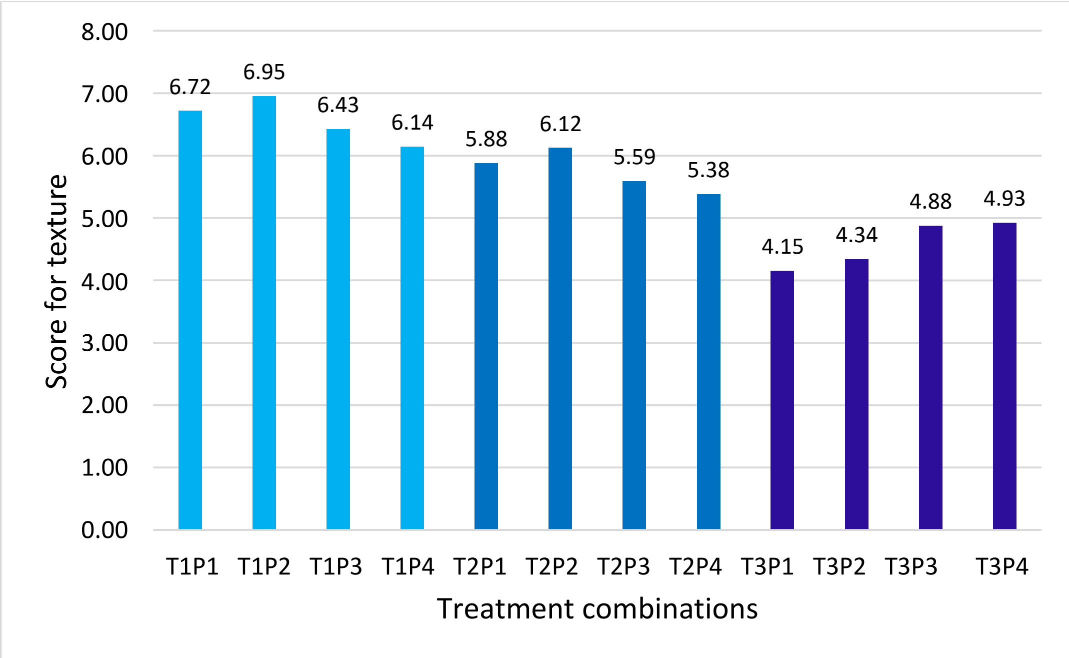


Fig- 4.25: Effect of storage methods and packaging materials on cumulative organoleptic score for texture of leaves in *A. chinense*

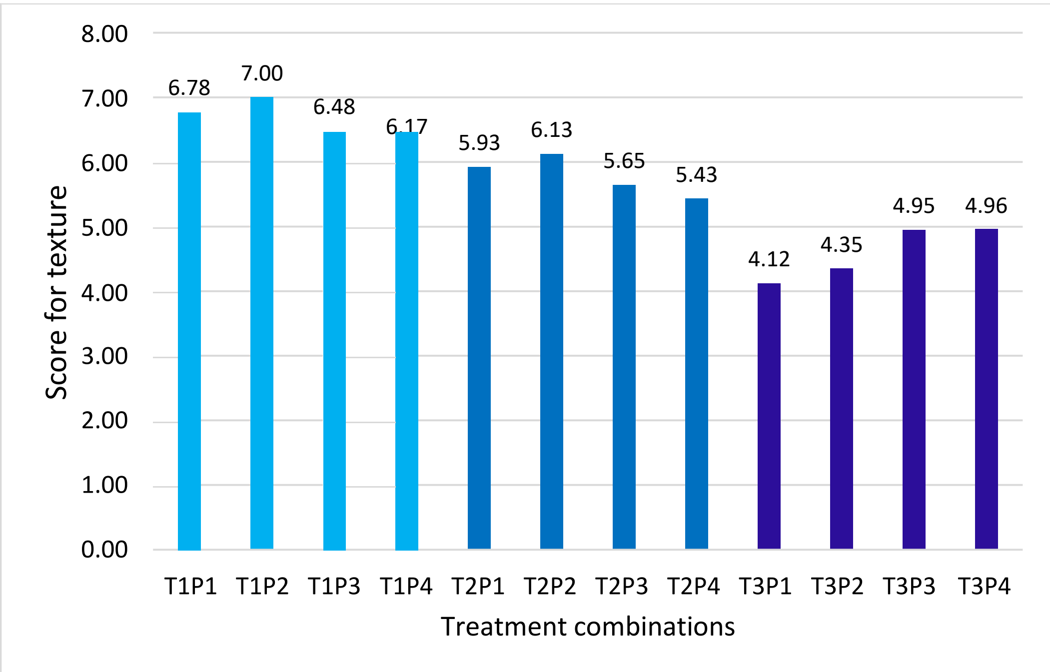


Fig- 4.26: Effect of storage methods and packaging materials on cumulative organoleptic score for odour of leaves in *A. tuberosum*

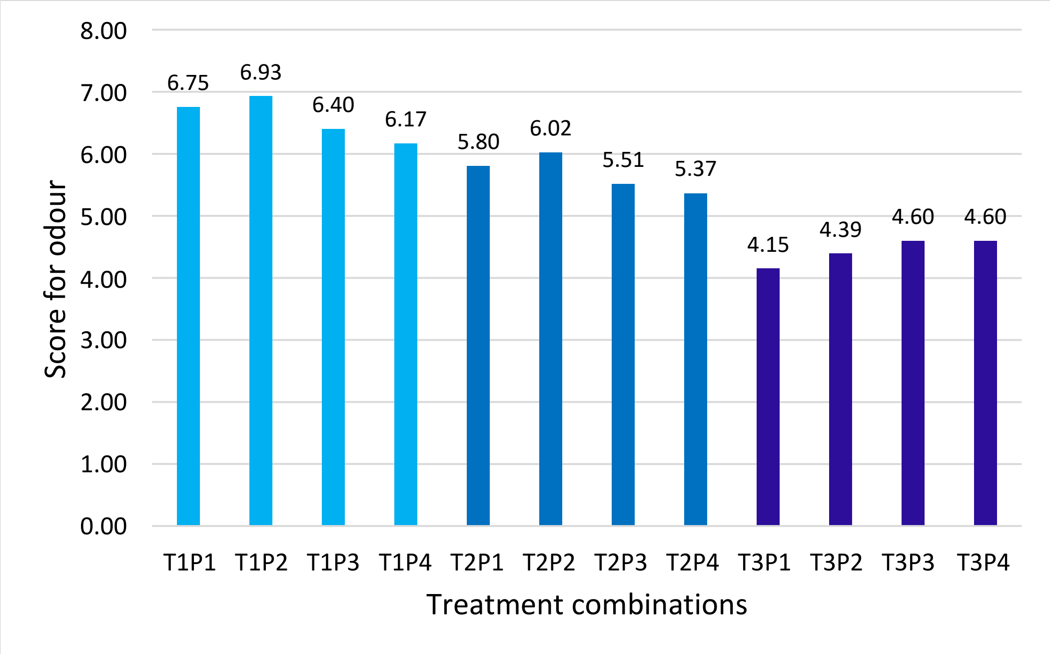


Fig- 4.27: Effect of storage methods and packaging materials on cumulative organoleptic score for odour of leaves in *A. chinense*

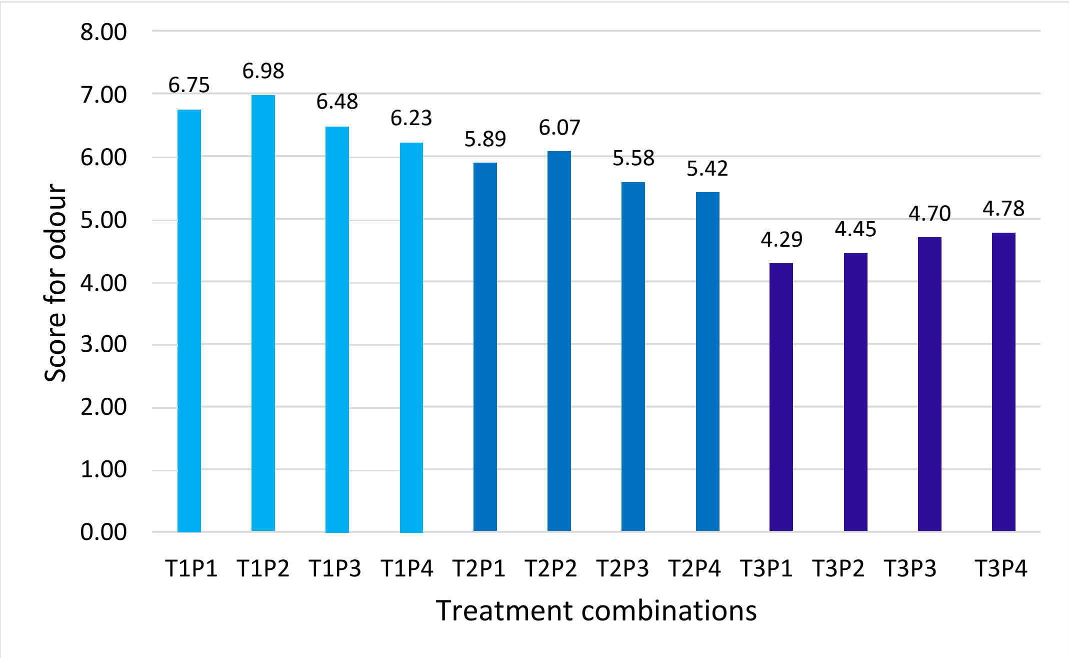


Fig- 4.28: Effect of storage methods and packaging materials on cumulative organoleptic score for overall acceptability of leaves in *A. tuberosum*

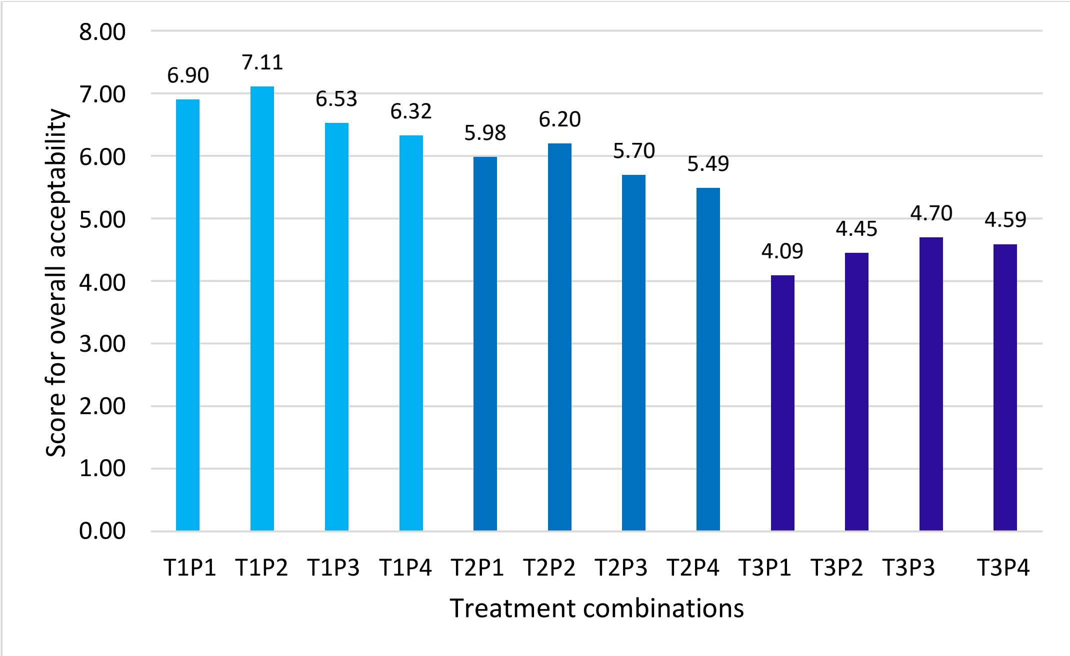


Fig- 4.29: Effect of storage methods and packaging materials on cumulative organoleptic score for overall acceptability of leaves in *A. chinense*

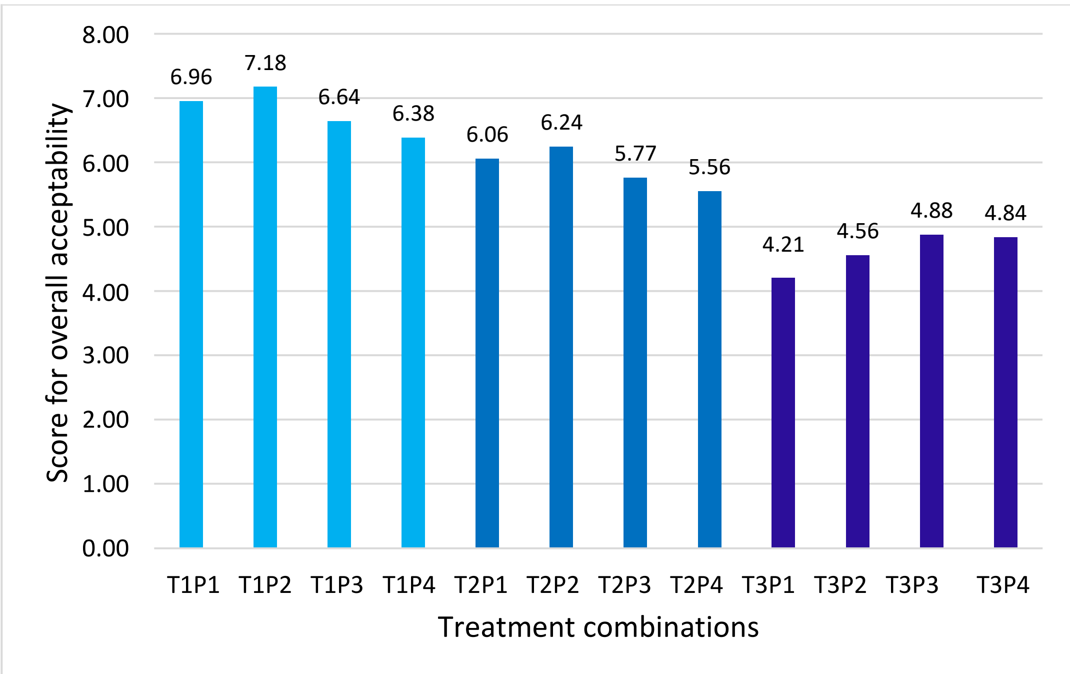


Table 4.21: Flowering and floral parameters of *Allium tuberosum*

Parameter	**Observations**
Season of flowering	December to March
Type of inflorescence	Umbel
Pedicel length of flower	1-1.5 cm
Flowering stem (scapes)	Solid and sharply angled
Flower colour	White
Number of flowers per umbel	58.5
Emergence of bud to opening of flower	12 days
Bud opening to full flowering	6.8 days
Days take from flowering to seed set	67 days
Length of flower stalk in fully developed flower	56.2 cm
Fruit type	Capsule
Number of seeds per umbel	80
Tepals	Elliptic, white in colour
Number of tepals per flower	6
Number of stamens per flower	6
Number of pistils per flower	1

Allium tuberosum produces fragrant, white six-stellate flowers in umbels, and the plants are hermaphroditic. The season of flowering in *Allium tuberosum* is December to March. The flowers are formed on umbel shaped inflorescence on solid and sharply angled scapes. There were about an average of 59 flowers present in each umbel. The pedicel length of the flowers was 1 to 1.5 cm. The flowers opened 12 days after the emergence of buds and reached full flowering stage in 6.8 days. Seed set occurred 67 days after flowering in capsules. There were about 80 seeds present in each umbel.

Single flower

Inflorescence (Umbel)

Fruit set

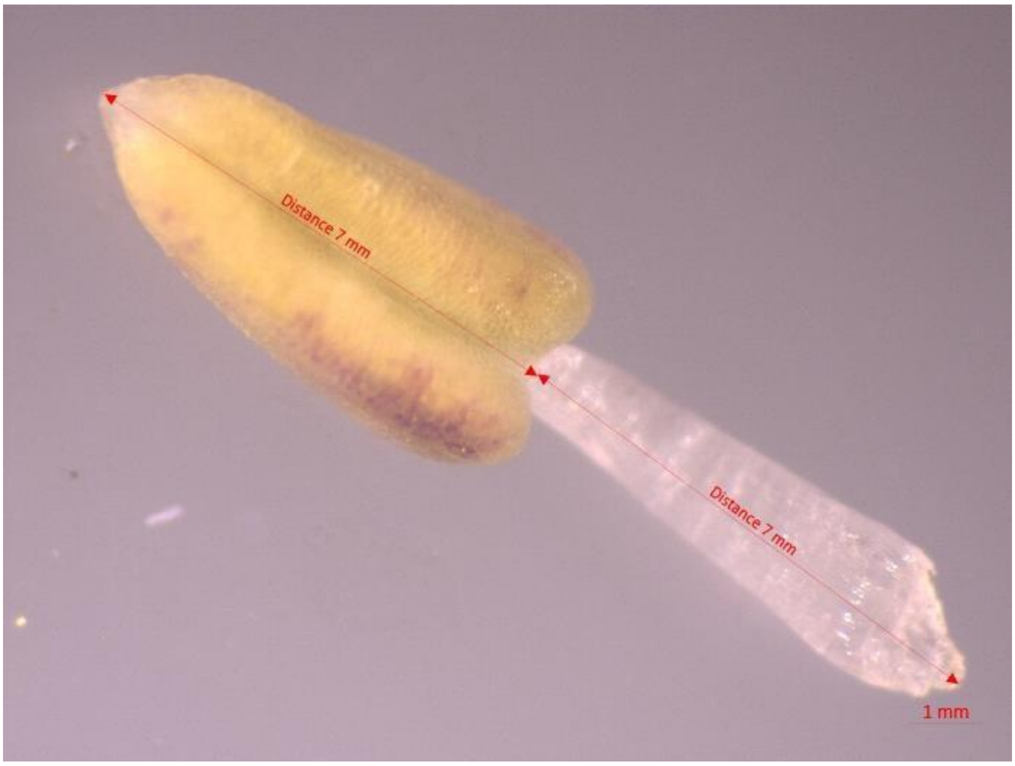
Seed set

Plate 10: Single flower, Inflorescence (Umbel), Fruit set and seed set in *Allium tuberosum*

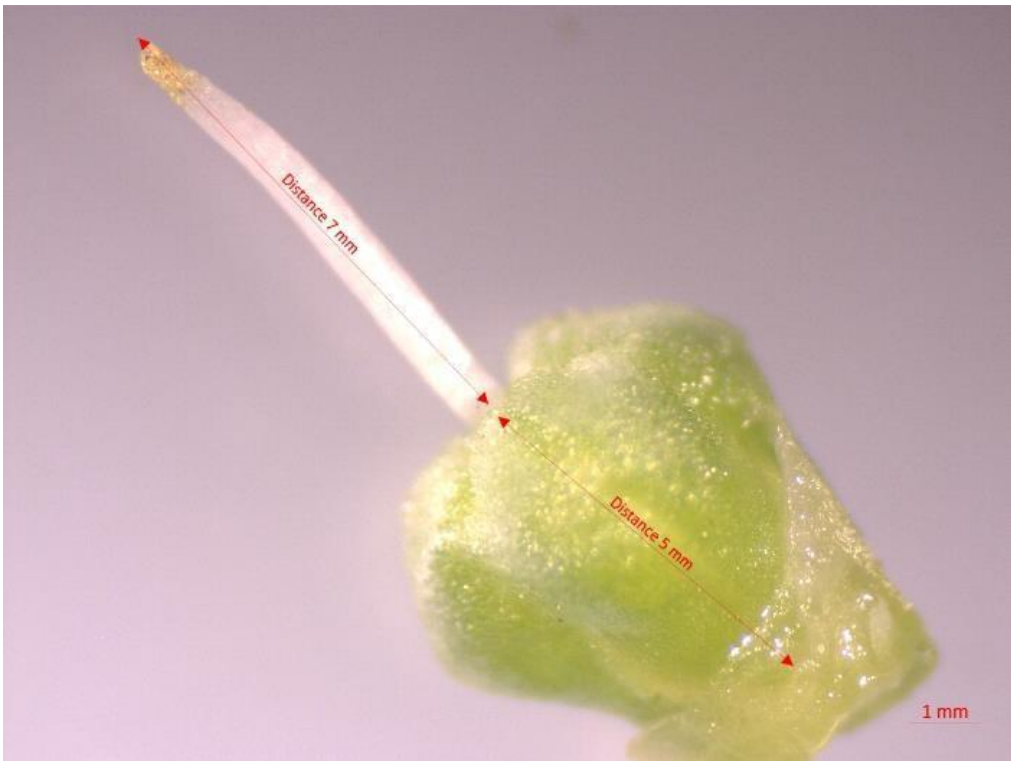
Long styled flower

Short styled flower

Plate 11: Multistyly in *Allium tuberosum* flower



Stamen



Pistil

Plate 12: Stamen and pistil of *Allium tuberosum* flower

Summary

5. SUMMARY

The experiment entitled "**Performance evaluation of underutilized edible *Alliums***" was conducted from October 2021 to May 2021 at the Department of Plantation Crops and Spices, College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur district, Kerala. The study used a completely randomised design with four treatment combinations and four replications of the two species, *A. tuberosum* and *A. chinense*, which were cultivated in growbags under rain shelter and open field conditions, separately. All biochemical analyses were carried out in the Department of Plantation Crops and Spices' well-equipped laboratory, the Department of Post-Harvest Technology's Quality Control lab, and the Department of Soil science and agriculture chemistry lab. Observations were recorded on twenty one economically important and biochemical traits viz; Number of leaves per plant, number of tillers, number of leaves per tiller, plant height measured in centimeter, leaf length (cm), leaf breadth (cm), leaf area (cm^2), foliage yield (g/plant), total chlorophyll (mg/g), chlorophyll 'a' (mg/g), chlorophyll 'b' (mg/g), total carotenoides (g/100g), dry matter (%), moisture content (%), relative water content (%), TSS (%), ascorbic acid (mg/g), phenol (mg/g), flavonoids (mg/g), total sugar (mg/g), reducing sugar (mg/g), non-reducing sugar (mg/g), sulphur (%) and effects of storage methods and packaging materials on physiological loss in weight (PLW) of leaves and organoleptic evaluation. The summary and conclusion of this experiment is presented below. Significant variation were found for majority of the characters under study. The following are the findings of this study.

***Allium* species**

- Morphological characteristics like plant height, number of tillers, leaf length, leaf breadth, leaf area and leaf yield were found to be highest in *Allium chinense* than *Allium tuberosum*. Whereas number of leaves per plant and number of leaves per tiller were higher in *Allium tuberosum* when compared to *Allium chinense*.

- Physiological characteristics like total chlorophyll, chlorophyll 'a', chlorophyll 'b', total carotenoids, moisture content and relative water content was found to be highest in *Allium tuberosum* compared to *Allium chinense*. Whereas dry matter content and TSS was found to be highest in *Allium chinense* when compared to *Allium tuberosum*.
- Biochemical characteristics such as ascorbic acid content, phenol content, total flavonoids, total sugars, reducing sugar and non-reducing sugar was high in *Allium chinense* compared to *Allium tuberosum*. Whereas sulphur content was found to be highest in *Allium tuberosum*.

Growing conditions

- All the morphological characteristics such as number of leaves per plant, number of tillers, number of leaves per tiller, plant height, leaf length, leaf breadth, leaf area and leaf yield were found significantly higher under open condition when compared to rain shelter.
- Physiological characteristics such as total chlorophyll, chlorophyll 'a', chlorophyll 'b', total carotenoids, moisture content and relative water content was found significantly higher when grown in rain shelter compared to open condition. Whereas dry matter content and TSS was found significantly higher when grown under open condition compared to rain shelter.
- Biochemical characteristics such as ascorbic acid content, phenol content, total flavonoids, total sugars, reducing sugar and sulphur content was found significantly higher when grown under open condition compared to rain shelter. Whereas non-reducing sugar was found significantly higher when grown in rain shelter compared to open condition.

Storage study of *Allium* leaves

The experiment was set up in completely randomised design with twelve treatment combinations and three replications. The treatment combinations included of three distinct storage conditions such as, refrigerated condition, cold storage and ambient condition and four types of packaging materials such as, 200-gauge LDPE, 200-gauge LDPE with perforation, brown paper bag and tissue paper wrapping. The observations with respect to physiological loss of weight and organoleptic properties were examined.

- Storage conditions and packaging materials influenced the physiological loss of weight and organoleptic quality of *Allium* leaves during storage period.
- The leaves of *Allium tuberosum* and *Allium chinense* stored in ambient conditions lost the most PLW compared to those held in cold storage and refrigerated conditions. In all storage conditions, the leaves packed in 200-gauge LDPE with perforation had the lowest PLW, followed by 200-gauge LDPE, and it was greatest in tissue paper wrapping, followed by brown paper bag.
- Among the *Allium* species, *A. chinense* showed lesser loss in physiological weight irrespective of storage conditions and packaging materials when compared to *A. tuberosum*.
- Regardless of storage conditions or packing materials, the organoleptic score for appearance, colour, texture, aroma, and overall acceptability decreased throughout storage.
- Leaves packed in 200-gauge LDPE with perforation and stored in refrigerated condition was found to be effective in maintaining the lowest PLW, appearance, colour, texture, odour, and overall acceptability throughout the storage period.

Flowering and floral parameters of *Allium tuberosum*

Allium tuberosum produces fragrant, white six-stellate flowers in umbels, and the plants are hermaphroditic. The season of flowering in *Allium tuberosum* is December to March. The flowers are formed on umbel shaped inflorescence on solid and sharply angled scapes. There were about an average of 59 flowers present in each umbel. The pedicel length of the flowers was 1 to 1.5 cm. The flowers opened 12 days after the emergence of buds and reached full flowering stage in 6.8 days. Seed set occurred 67 days after flowering in capsules. There were about 80 seeds present in each umbel.

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Appendix 1.

Meteorological data during the period of observation

Monthly data (2020-2021)						
Month	**Temperature (℃)**		**RH (%)**			**Rainfall (mm)**
	Max.	**Min.**	**I**	**II**	**Mean**	
November-2020	33	22	85	55	70	56.1
December-2020	32.3	21.9	75	55	65	7.7
January-2021	32.3	21.3	78	50	64	45.7
February-2021	34.6	21.6	70	38	54	0.0
March-2021	36.8	23.0	84	34	59	31.8
April-2021	34.9	23.6	89	58	74	72.4
May-2021	32.7	22.9	94	73	84	550.5

ERFORMANCE EVALUATION OF UNDERUTILIZED EDIBLE *ALLIUMS*

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Allium L. is one of the largest genera in the Amaryllidaceae, with around 900 species distributed throughout the world. Indian gene centre is fairly rich in wild species (about 30) mostly confined to Himalayas. *Allium* species may differ in appearance and flavour, yet biochemically, they are quite similar. Wild *Allium* species are the good source of biologically active phytomolecules, including organosulphur compounds, phenolic acids, flavonols, vitamins and nutrients. Underutilised *Alliums* can be an excellent substitute for onion and garlic in different regions of India, due to their wider adaptability and multipurpose usage, especially under the current unpredictable climatic conditions. It is in this context that, the current experiment entitled **Performance evaluation of underutilized edible *Alliums*** was taken up with the broad objective of morphological characterization and biochemical analysis of underutilised edible *Alliums* namely *Allium tuberosum* and *Allium chinense* under Kerala conditions and to standardise the storage methods.

The study used a completely randomised design with four treatment combinations and four replications of the two species, *A. tuberosum* and *A. chinense*, which were cultivated in grow bags under rain shelter and open field conditions, separately. The observations recorded are number of leaves per plant, number of tillers per plant, number of leaves per tiller, plant height, leaf length, leaf breadth, leaf area and foliage yield. Physiological and biochemical parameters such as total chlorophyll, chlorophyll ‘a’, chlorophyll ‘b’, total carotenoides, dry matter, moisture content, relative water content, TSS, ascorbic acid, phenol, flavonoids, total sugar, reducing sugar, non-reducing sugar, and sulphur content were studied. The findings reveal that variability was present between the *Allium* species, as well as between the growing conditions under study. For storage study, the experiment was set up in completely randomised design with twelve treatment combinations and three replications. The treatment combinations included of three distinct storage conditions such as, refrigerated condition, cold storage and ambient

condition and four types of packaging materials such as, 200-gauge LDPE, 200-gauge LDPE with perforation, brown paper bag and tissue paper wrapping, the observations with respect to physiological loss of weight and organoleptic properties were examined.

Among *Allium* species, morphological characteristics like plant height, number of tillers, leaf length, leaf breadth, leaf area and leaf yield were found to be significantly higher in *Allium chinense* than *Allium tuberosum*, whereas number of leaves per plant and number of leaves per tiller were significantly higher in *A. tuberosum* when compared to *A. chinense*. Physiological characteristics like total chlorophyll, chlorophyll 'a', chlorophyll 'b', total carotenoids, moisture content and relative water content was found to be highest in *A. tuberosum* compared to *A. chinense,* whereas dry matter content and TSS were found to be highest in *A. chinense* when compared to *A. tuberosum*. Biochemical characteristics such as ascorbic acid, total phenols, total flavonoids, total sugars, reducing sugar and non-reducing sugar was high in *A. chinense* compared to *A. tuberosum,* whereas sulphur content was found to be highest in *A. tuberosum*.

Among the growing conditions, all the morphological characteristics such as number of leaves per plant, number of tillers, number of leaves per tiller, plant height, leaf length, leaf breadth, leaf area and leaf yield were found significantly higher under open condition when compared to rain shelter. Physiological characteristics such as total chlorophyll, chlorophyll 'a', chlorophyll 'b', total carotenoids, moisture content and relative water content was found significantly higher when grown in rain shelter compared to open condition, whereas dry matter content and TSS was found significantly higher when grown under open condition compared to rain shelter. Biochemical parameters such as ascorbic acid content, phenol content, total flavonoids, total sugars, reducing sugar and sulphur content was found significantly higher when grown under open condition compared to rain shelter, whereas non-reducing sugar was found significantly higher when grown in rain shelter in *A. tuberosum* and it is found higher under open condition in case of *A. chinense*.

Storage study revealed that, storage conditions and packaging materials influenced the physiological loss of weight and organoleptic quality of *Allium* leaves during storage. The leaves of *Allium tuberosum* and *Allium chinense* stored in ambient conditions exhibited the most PLW compared to those held in cold storage and refrigerated conditions. In all storage conditions, the leaves packed in 200-gauge LDPE with perforation had the lowest PLW, followed by 200-gauge LDPE, and it was greatest in tissue paper wrapping, followed by brown paper bag. Among the *Allium* species, *A. chinense* showed lesser loss in physiological weight irrespective of storage conditions and packaging materials when compared to *A. tuberosum*. Regardless of storage conditions or packing materials, the organoleptic score for appearance, colour, texture, aroma, and overall acceptability decreased with prolonged storage. Leaves packed in 200-gauge LDPE with perforation and stored in refrigerated condition was found to be effective in maintaining the lowest PLW, appearance, colour, texture, odour, and overall acceptability throughout the storage period and with maximum shelf life of 15 days for *Allium chinense* and 12 days for *Allium tuberosum*.

Allium tuberosum produces fragrant, white six-stellate flowers in umbels, and the plants are hermaphroditic. There were about an average of 59 flowers present in each umbel. The flowers opened 12 days after the emergence of buds and reached full flowering stage in 6.8 days. Seed set occurred 67 days after flowering in capsules. There were about 80 seeds present in each umbel.