Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas

Jauhar Rafeeq
(2020-1004-D)

Faculty of Forestry

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

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Dedicated

To my Advisor and Beloved Parents

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

Certificate – I

This is to certify that the thesis entitled, **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosphy in Forestry**, to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Jauhar Rafeeq (Regd. No. 2020-1004-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Prof. & Head,
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Dean,
Faculty of Forestry

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

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We, the members of the Advisory Committee of **Mr. Jauhar Rafeeq (Regd. No. 2020-1004-D)** a candidate for the degree of **Doctor of Philosphy in Forestry** have gone through the manuscript of the thesis entitled, **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Prof. (Dr.) K.N Qaisar
Professor and Controller of Examinations, SKUAST-K

Members

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Professor and Head, Division of
FBT, FOF, SKUAST-K

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

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This is to certify that the thesis entitled, **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** submitted by **Mr. Jauhar Rafeeq (Regd. No. 2020-1004-D))** to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosphy in Forestry (Silviculture and Agroforestry)** was examined and approved by the Advisory Committee and External Examiner on **14-11-2023.**

Chairman
Advisory Committee

External Examiner
Dr. Sanjeev Kumar
Professor and Dean,
College of Forestry,
Banda University of
Agriculture and Technology

Prof. & Head,
Division of Silviculture and Agroforestry

Dean,
Faculty of Forestry

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

Name of the student : **Jauhar Rafeeq**

Registration No. : 2020-1004-D

Major Subject : **Forestry**

Minor Subject : Silviculture and Agroforestry

Major Advisor : **Prof. (Dr.) K.N Qaisar**
Professor and Controller of Examinations,
SKUAST-Kashmir

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ABSTRACT

The present investigation entitled, "Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas" presents a comprehensive investigation conducted between 2020 and 2023, unveiling crucial insights into various facets of Hawthorn, *Crataegus songarica*. This study encompasses the plant's phenology, population ecology, propagation techniques and chemical composition within the unique ecosystem of Kashmir Himalayas.

In experiment I, phenology and population ecology of *Crataegus songarica* was studied. The phenology of crataegus species was studied to generate baseline data and were described in different phases of growth throughout the seasons. The observations for the year 2021 indicate that bud set began in the third week of February, followed by bud bursting in the fourth week of March. By the first week of April, the leaves were fully open. Flowering started in the fourth week of April and continued until the fourth week of May, with the peak occurring in the second week of May. Fruit initiation was observed in the fourth week of July, while fruit fall started in the second week of September and lasted until the third week of October. Leaf tint was observed during the third week of September and leaf fall commenced in the fourth week of September,

continuing until the first week of November. Investigations revealed that the entire phenophase cycle of *Crataegus songarica* lasted 9 months and 3 weeks. The observations from 2022 indicated the early emergence of phenological events by 1 week due to the higher temperature in that year as compared to 2021. The entire phenophase cycle of *Crataegus songarica* in 2022 lasted 9 months and 3 weeks. By comparing these two year data of 2021 and 2022, we can gain insights into the variations in the phenological patterns of *Crataegus songarica* and better understand the impact of environmental factors on its life cycle.

For population ecology studies, surveys were conducted in ten Forest Divisions of Kashmir Himalayas namely, Sindh Forest Division, Bandipora Forest Division, Budgam Forest Division, Tangmarg Forest Division, Shopain Forest Division, Anantnag Forest Division, Langate Forest Division, Kamraj Forest Division, Kehmil Forest Division and Baramulla Forest Division. The data was collected at each site where *Crataegus songarica* were found abundantly. The relative values of frequency, density and basal area were combined to calculate the Importance Value Index (IVI) for each species, which represents their dominance. Studies conducted revealed that a total of 34 species were observed to grow alongside *Crataegus songarica*. Among these species, there were 11 trees, 7 shrubs and 16 herbs. The tree species found included *Ailanthus altissima, Aesculus indica, Abies pindrow, Cedrus deodara, Celtis australis, Juglans regia, Morus nigra, Morus alba, Robinia pseudoacacia, Pinus walliachiana* and *Ulmus villosa*. Meanwhile the shrubs that were identified included *Berberis lyceum, Parrotia jacquemontiana, Rosa webbiana, Sambucus wightiana, Vibernum grandiflorum* and *Indigofera heterantha*. Additionally, herb species found included *Artimesia absinthium, Cynodon dactylon, Cannabis sativa, Conyza Canadensis, Dactylis glomerata, Fragaria vesca, Fritillaria imperialis, Hypericum perforatum, Mentha spicata, Malva neglecta, Podophyllum hexandrum, Rumex nepalensis, Trifolium repens, Taraxacum officinale, Urtica dioica and Viola odorata*. These species belonged to 23 families, with Pinaceae, Fabaceae, Rosaceae and Asteraceae being the dominant families, each comprising 3 species. The IVI of *Crataegus songarica* was found highest (85.07) for Langate Forest Division. The lowest IVI was recorded for Kamraj Forest Division (46.28).

For trees, the highest Shannon Wiener diversity index (3.21) was observed in the Anantnag Forest Division, showcasing the richness of tree species in this region. Conversely, the lowest diversity index (1.69) was recorded in the Shopian Forest Division, indicating lower tree species diversity in this area. In the case of shrubs, the Sindh Forest Division exhibited the highest diversity index (1.73), highlighting a rich diversity of shrub species. Conversely, the Langate Forest Division showed the lowest diversity index (1.03) among shrubs, indicating comparatively lower shrub species richness. Among herbs, the Kamraj Forest Division recorded the highest Shannon Wiener diversity index (3.97), signifying a diverse and rich herbaceous plant community. In contrast, the Bandipora Forest

Division exhibited the lowest diversity index (2.46) for herbs, suggesting relatively lower herb species diversity in this area.

In experiment II, *Crataegus songarica* was propagated from both seeds and cuttings. The seeds of *Crataegus songarica* were randomly collected in the month of September from trees located at different sites in the study area. After collection, the morphometric characteristics of *Crataegus songarica* seeds viz. seed weight, seed diameter, seed length and seed moisture were studied. Different treatments were given to seeds i,e scarification with concentrated sulfuric acid (concentration 50%) alone for 1 hour, scarification with concentrated sulfuric acid for 1 hour and then subjected to cold stratification at about 4°C (40, 50, 60 and 70 days) and mechanical scarification with hammer. The findings indicated that Hawthorn showed significant variability in seed weights, ranging from a minimum of 9.67 g to a maximum of 13.48 g per 100 seeds, with an average of 11.49 g per 100 seeds. In terms of seed diameter, Hawthorn exhibited a span of 4.39 mm to 6.64 mm, with an average diameter of 5.65 mm. The length of the seeds ranged from 7.26 mm to 8.21 mm, with an average length of 7.67 mm. Additionally, the seed moisture content of Hawthorn ranged from 7.96% to 9.31%, with an average moisture content of 8.46%. The seed propagation studies showed that scarification and stratification treatments had a significant impact on germination, root development and growth of *Crataegus songarica*. Among all the treatments the highest germination percentage of 36.66, germination energy (31.66%), germination value (4.21), seedling height (14.37 cm), vigour index (526.26) and total leaf area (27.71 cm^2) was recorded in seeds that were subjected to scarification with concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. In contrast, the control group (untreated seeds) exhibited the lowest germination percentage of 10.00%, germination energy (6.66) germination value (0.62), seedling height (5.64 cm), vigour index (56.40) and total leaf area (23.21 cm^2) . These findings have important implications for seed propagation, nursery management, and ecological restoration projects involving Hawthorn.

In case of vegetative propagation studies, cuttings of *Crataegus songarica* were treated with IBA and NAA at varying concentrations (1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm, 5000 ppm and 6000 ppm) before planting. Studies conducted revealed that cuttings treated with IBA at concentration of 4000 ppm showed best results in terms of highest values for sprouting percentage (93.33%), rooting percentage (76.66%), average number of roots per cutting (17.33), average root length (11.03 cm), collar diameter of leading shoot (7.03 mm), leaf area (28. 68 cm^2) and average plant height (27.53 cm). The minimum values for all the parameters were recorded for control (untreated cuttings). Cuttings treated with IBA 4000 ppm showed best results and may be used for mass propagation of *Crataegus songarica*. These results provide valuable insights for the propagation and cultivation of the studied plant species, allowing for the optimization of hormone concentrations to maximize growth and root development.

In experiment III, leaf and fruit specimens were collected randomly from wild growing *Crataegus songarica* from different sites located in the study area. The fruits and leaves were the evaluated for total soluble solids, total phenolic content, total flavonoid content and antioxidant activity. Fruits exhibited significantly higher levels of total phenolic content (38.28 mg GAE/g DW for Malhar Ganderbal, 34.09 mg GAE/g DW for Babareshi Gulmarg, 33.39 for Dachigam National Park, Srinagar, 33.68 mg GAE/g DW for Ajas Bandipora and 34.10 mg GAE/g DW for Shikergah Tral) and greater antioxidant activity (1.71 mmol Fe++/g DW for Malhar Ganderbal, 1.20 for mmol Fe++/g DW Babareshi, Gulmarg, 0.92 mmol Fe++/g DW for Dachigam National Park, Srinagar, 0.64 mmol Fe++/g DW for Ajas Bandipora and 0.69 mmol Fe++/g DW for Shikergah Tral) in comparison to leaves (Total phenolic content viz. 28.58mg GAE/g DW for Malhar Ganderbal, 27.07 mg GAE/g DW for Babareshi Gulmarg, 26.48 for Dachigam National Park, Srinagar, 26.25 mg GAE/g DW for Ajas Bandipora and 25.70 mg GAE/g DW for Shikergah Tral, antioxidant activity viz. 0.93 mmol Fe++/g DW for Malhar Ganderbal, 0.88 for mmol Fe++/g DW Babareshi, Gulmarg, 0.75 mmol Fe++/g DW for Dachigam National Park, Srinagar, 0.91 mmol Fe++/g DW for Ajas Bandipora and 0.90 mmol Fe++/g DW for Shikergah Tral). This implies that hawthorn fruits possess enhanced potential for contributing to antioxidant-rich dietary sources and potential health benefits. Conversely, hawthorn leaves were found to contain elevated concentrations of total flavonoids (7.41 mg QUE/g DW for Malhar Ganderbal, 7.87mg QUE/g DW for Babareshi, Gulmarg, 7.15 mg QUE/g DW for Dachigam National Park, Srinagar, 6.58 mg QUE/g DW for Ajas Bandipora and 6.41 mg QUE/g DW for Shikergah Tral) compared to hawthorn fruits (4.82 mg QUE/g DW for Malhar Ganderbal, 5.71 mg QUE/g DW for Babareshi, Gulmarg, 4.53 mg QUE/g DW for Dachigam National Park, Srinagar, 3.51 mg QUE/g DW for Ajas Bandipora and 3.62mg QUE/g DW for Shikergah Tral) , indicating a preference for leaf-derived flavonoids as potential natural remedies.

Key words: *Crataegus songarica*, Hawthorn, Kashmir Himalayas, Phenology, Population ecology, IVI, Shannon Wiener diversity index, Propagation, Seed, Scarification, Cuttings, IBA, Chemical profiling, Fruit, Leaves

Signature of Student
Dated_____

Signature of Major Advisor
Dated _____

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Jauhar Rafeeq

Place: Benhama, Ganderbal
Dated: _____

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Chapter 1

INTRODUCTION

Wild edible plants, including hawthorn, have played an integral role in human life throughout history. These plants have provided essential resources such as fruits, seeds, leaves, flowers, roots and branches, catering to personal and social needs, ranging from sustenance to medicinal purposes and environmental enhancement (Hricova *et al*., 2016; Zorenc *et al*., 2016). The genus Crataegus, commonly known as hawthorn, comprises over 1000 species and belongs to the subfamily Maloideae in the Rosaceae family. This genus is widely distributed in Asia, Europe and North America (Alirezalu *et al*., 2018). One notable species within the Crataegus genus is *Crataegus songarica*, commonly referred to as hawthorn or thorn apple. It possesses various vernacular names in different regions. In the Kashmir valley, it is known as Ring kul, Ban-Sangli (Hindi and Punjabi), Goni (Chitrali), Dakh (Kishtwar), Batsinga (Allai Valley and Western Himalaya, Pakistan), Pingyat (Lahaul, Himachal Pradesh) and Dolana (Guldara, Kabul) (Anwar *et al*., 1979; Shah and Hussain, 2012; Kumar *et al*., 2009; Haq, 2012; Rawat *et al*., 2010).

Crataegus songarica is a shrubby tree that can grow up to 4-5 meters in height, with multiple trunks ranging from 5-9 centimeters in diameter. The bark of the tree displays varying colors from reddish gray to blackish, characterized by small cracks. Its leaves measure approximately 6-8 centimeters in length and 5-6 centimeters in width, accompanied by petioles. The leaf shape is broadly triangular to nearly circular, exhibiting 5-7 lobes with dentate margins. Young twigs of the plant are either smooth or slightly hairy and they feature spines measuring up to 1.7 centimeters in length. Distinguishing itself from other species, *Crataegus songarica* can be identified by its smooth, brown older branches and reddish-brown year-old twigs (Zaurov *et al*., 2012). *Crataegus Songarica* is distributed across various regions including Afghanistan, Iran,

northern India, northern Pakistan, Tadzhikistan, Kyrgyzstan, Uzbekistan, Kazakhstan and Sinkiang. Its habitat spans an altitude range of 800-2700 m amsl. In India, it is commonly found in the mountainous regions, specifically in river valleys and on ravine slopes in the temperate Himalayas of Kashmir and Himachal Pradesh, at an altitude of 1800-3000 m amsl (Nadkarni, 1976). It is also present in Afghanistan and Uttar Pradesh, ranging from 1500 to 2700 m amsl in altitude. In Jammu and Kashmir, it can be found in various areas such as Lolab, Sindh valley, Gulmarg, Pahalgam and the Pirpanjal Range (Lone *et al*., 2014). Additionally, *Crataegus songarica* is abundant in the Kashmir Valley, specifically at altitudes ranging from 1700 to 1900 meters above sea level (Stewart, 1972).

According to a report by Nabavi *et al*., (2015), hawthorn, including its fruits, leaves and flowers, has been found to possess various medicinal properties. These parts of the hawthorn plant are commonly used for their antispasmodic, cardiotonic, hypotensive, diuretic and atherosclerotic effects. A global examination of hawthorn has uncovered the existence of diverse advantageous components like flavonoids, titerpenoids, procyanidins and phenolic acids. These compounds are responsible for the pharmacological activities associated with hawthorn (Barros *et al*., 2010). The fruits of the Crataegus plant are particularly rich in phenolic compounds, which are utilized as medicinal remedies due to their diverse biological activities (Li and Wang, 2011). Furthermore, both the fruits and leaves of Crataegus serve as excellent sources of antioxidants. This is attributed to their high phenolic content and the presence of well-known antioxidant compounds such as hyperoside, isoquercetin, epicatechin, chlorogenic acid, quercetin, rutin and protocatechuic acids (Zugic *et al*., 2014).

Phenology refers to the examination of recurring life cycle events and their connection to seasonal and yearly variations in climate, as well as habitat factors like elevation. By observing phenological changes, we gain detailed information about the ongoing impacts of global warming over time (Chhetri *et al*., 2020). The patterns of plant phenology, which result from plants responding to specific

environmental conditions, exhibit significant variation across different spatial and temporal scales worldwide. Global changes, including climate change, are impacting the composition and functioning of various ecosystems and their vegetation characteristics. Among the sensitive indicators of these changes are plant phenological patterns, which are expected to be altered due to global climate change (Kushwaha *et al*., 2011).

The analysis of tree phenology offers a valuable tool for investigating crucial questions related to modeling and monitoring climate change. As a result, phenological research has increasingly focused on understanding how global climate change will affect phenology and the potential consequences for species distribution and ecosystem function (Singh and Kushwaha, 2005). Key climatic factors such as temperature and precipitation play a significant role in determining the seasonality of plant phenology (Marques *et al*., 2004). The study of phenological events is valuable for developing effective management strategies and gaining a deeper understanding of natural forest regeneration potential and community-level interactions (Fox, 1976).

Seed propagation is a cost-effective and efficient method for mass plant propagation. In recent centuries, there has been a growing interest in controlled reforestation as a means to replenish extensive areas that have been depleted of natural forests. To meet this demand, billions of seeds are produced annually (Hartmann *et al*., 2002). The germination of seeds plays a crucial role, particularly in afforestation efforts through natural or artificial means. Different species and seeds from various regions exhibit varying germination responses, making it essential to understand these differences for successful plantation programs. Additionally, while a species may be found in diverse climatic regions, its germination behavior can vary depending on its provenance. It is worth noting that the germination of seeds can be influenced by the specific nursery techniques employed.

The utilization of vegetative means for multiplication provides the advantage of achieving greater uniformity and immediate availability of superior clones for plantation purposes. This approach allows for obtaining plants with desired characteristics promptly and efficiently. The success of rooting stem cuttings relies on appropriate environmental treatment. Several researchers (Libby, 1974; Khosla *et al*., 1982) have demonstrated the potential for increased genetic gain in forest trees through vegetative propagation. In breeding programs and large-scale forestry operations, vegetative propagation serves as a crucial tool for the direct mass multiplication and preservation of desired or improved genotypes. Clonal plants produced through vegetative propagation, derived from a single mother tree possessing highly desirable genetic qualities such as high yield, rapid growth, good quality, disease resistance and stress tolerance, exhibit uniformity and retain all the genetic attributes of the mother plant. Clonal forestry also offers the advantage of exploiting genotype x environment interaction by deploying tested clones that are best suited for specific sites (White *et al*., 2007). Vegetative propagation enables the propagation of selected individuals in the shortest possible time, ensuring a consistent supply of planting stock on an annual basis. Various methods, including cutting, grafting, budding, layering and tissue culture, can be used for vegetative propagation. Among these methods, propagation through stem cuttings is the most widely employed technique due to its simplicity, speed and cost-effectiveness for replicating desired species or clonal materials (Hartmann and Kester, 1986).

This study aims to explore the various aspects of *Crataegus songarica*, including its phenology, population ecology, propagation techniques and phytochemical composition in Kashmir Himalayas. The examination of this specific hawthorn species aims to provide insights into its significance and potential advantages, thereby contributing to the broader comprehension and appreciation of wild edible plants as a whole. Considering the limited available information regarding the species in Kashmir Himalayas, this study titled

"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas" was undertaken with following main objectives.

- To study phenology and population ecology of *Crataegus songarica*.
- To study propagation of *Crataegus songarica* through seeds and cuttings.
- To study the chemical profiling of *Crataegus songarica*.

Chapter 2

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the literature pertaining to different aspects of present investigation entitled **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"**. Since literature related to different aspects of *Crataegus songarica* has not been adequate enough to highlight the research findings of the present investigation, therefore, cross references of other related species have also been taken into consideration. Attempts have been made to assemble the available research findings under the following broad heads:

2.1 Studies on phenology

2.2 Studies on Floristic diversity

2.3 Studies on propagation through seeds

2.4 Studies on Propagation through cuttings

2.5 Studies on chemical profiling

2.1 Studies on phenology

The reviewed literature focuses on the phenology of various tree species across different geographic locations and altitudinal gradients.

Chhetri *et al*., (2020) conducted an investigation at the Forest Research Institute in Dehradun, India. Their study focused into the phenological trends exhibited by a selection of tree species. These species, amounting to a total of 11, were chosen as the focal points of the research. The objective was to closely observe various phenological behaviors such as leaf emergence, leaf expansion, senescence, budding and ripening, among others. The preliminary phenophase that drew attention was the budding of leaves, which manifested primarily in February (36.36%), March (45.46%), and April (18.18%). Noteworthy variations

in phenophase activities were identified between February and June, marking a period of heightened sensitivity across the majority of the studied tree species. Notably, the emergence of leaves and the budding of flowers predominantly transpired during March (63.64%), while the peak of flowering was recorded in both March (54.55%) and April (27.27%). Likewise, the span encompassing fruiting stages, including fruit emergence and budding, unfolded from April through June.

Singh and Negi (2018) conducted a study on tree line species, including *Abies spectabilis*, *Betula utilis*, *Quercus semecarpifolia*, and *Rhododendron arboreum*. They found that leaf bud-break in these species occurred in May, but leaf initiation was delayed by approximately 2 months compared to mid-altitude tree species. The study suggested that with increasing warming rates, the phenological behavior of tree line species is expected to change significantly, leading to alterations in ecosystem properties.

Nanda *et al*., (2017) investigated the phenology of tree species in a tropical evergreen forest in southern India. They identified and tagged woody stems of 47 tree species and made observations on leafing, flowering, and fruiting phenophases. The study revealed that, except for leaf senescence, different phenophases of vegetative and reproductive phenologies exhibited significant seasonality at the community level.

Mir *et al*., (2016) focused on the phenology of Himalayan birch (*Betula utilis*) along altitudinal gradients in Kashmir Western Himalayas. The researchers observed phenological events, such as bud set, bud burst, peak flowering, and seed maturation, at different elevations. The study found a high synchrony throughout the altitudinal gradients, with phenological events occurring earlier at lower elevations. The timing of these events was influenced by snow-melt, which triggered early phenological changes in the northern alpine habitats.

Dantas *et al*., (2016) conducted a study on the phenology of *Carapa guianensis*, a multi-use tree species, in a floodplain forest of the Amazon estuary in Varzea forest. The researchers recorded flowering, fruiting, and leaf flush and fall for 30 individual trees over a 25-month period. They found that flowering peaked during the driest months, while leaf flush and fall did not show a strong seasonal pattern.

Kumar *et al*., (2014) studied the phenology of different tree species in South Gujarat. Their findings showed that vegetative growth, initiated by leaf flushes in March to April, was completed by May in most species. Deciduous trees exhibited flower and fruit formation in March, a month earlier than evergreen trees. Additionally, fruit maturation occurred one month ahead in deciduous species.

Bajpal *et al*., (2012) conducted a phenological study of two dominant tree species in a tropical moist deciduous forest in northern India. They assigned unique numbers to 10 selected sample trees and recorded observations on leaf flush, flowering, and fruiting events. The study indicated that most of the observed phenological events were influenced by photoperiod and temperature.

Prasad and Hedge (1986) investigated phenology and seasonality in a tropical deciduous forest in Bandipur, South India. The study revealed patterns of strong seasonality in leaf and fruit initiation, with little inter-annual variation observed in flowering and fruiting events.

Overall, the reviewed literature provides valuable insights into the phenological behavior of tree species across diverse ecological settings. The studies highlight the influence of environmental factors, such as altitude, temperature, photoperiod and precipitation, on the timing and synchronization of phenological events. Understanding these phenological patterns is crucial for predicting the potential impacts of climate change on ecosystem dynamics and functioning.

2.2 Studies on Floristic diversity

Phytosociological studies play a crucial role in the protection of natural plant communities and biodiversity by providing valuable insights into past and ongoing changes. These studies contribute to our understanding of species diversity, community composition, structure and development (Li *et al*., 2002). Species diversity serves as a significant indicator for assessing the stability and sustainability of forest communities. It provides essential information for effective forest management, considering aspects such as economic value, regeneration potential and conservation of biological diversity (Verma *et al*., 1999).

Aijaz *et al*., (2022) conducted a study centered around the floristic diversity within the Overa wildlife sanctuary located in the Kashmir Valley. The research involved an analysis of vegetation using stratified random sampling. Quadrates with dimensions of 10×10 m, 5×5 m, and 1×1 m were employed for trees, shrubs and herbs, respectively, across all four habitats. The outcomes of the investigation highlighted the plant community composition and various phytosociological characteristics of the vegetation. A total of 37 plant species, originating from 25 distinct families, were documented within the study area. These species were further categorized into 8 tree species, 8 shrub species, and 21 herb species. Among the recorded families, the most prevalent was Asteraceae, comprising 4 species, followed by Pinaceae and Fabaceae, each with 3 species. Additional families, including Malvaceae, Poaceae, Polygonaceae, Rosaceae, and Sapindaceae, were each represented by two species. Several other families such as Betulaceae, Dioscoreaceae, Berberidaceae, Caprifoliaceae, Juglandaceae, Simaroubaceae, Hamamelidaeae, Cupressaceaea, Ranunculaceae, Lamiaceae, Phytolacaceae, Podophyllaceae, Solanaceae, Cannabaceae, Poaceae, Urticaceae, and Valerianaceae were each represented by one species. The phytosociological analysis of different habitats revealed that *Abies pindrow* and *Pinus wallichiana* predominantly occupied the woodland and riverine environments, whereas *Abies pindrow* and *Picea smithiana* were dominant in the coniferous habitat.

Additionally, *Betula utilis and Picea smithiana* exhibited dominance in the sub-alpine pasture habitat. Among shrubs, *Viburnum grandiflorum* emerged as the most dominant species in woodland, riverine, and coniferous habitats, while *Juniperous communis* held dominance in the sub-alpine pasture habitat. Similarly, for herbs, *Fragaria vesca* exhibited dominance in woodland, riverine, and coniferous habitats, while *Trifolium repens* held dominance in the sub-alpine pasture habitat. In terms of diversity, the Shannon Wiener diversity index was calculated. For trees, the index values were 1.60 in the woodland and 1.37 in the coniferous habitat. Among shrubs, the diversity index was 1.92 in the woodland and 1.08 in the sub-alpine pasture. Lastly, for herbs, the index values were 2.68 in the woodland and 3.27 in the sub-alpine pasture habitat, while being 2.15 in the overall study area.

Mugloo *et al.*, (2021) conducted a research endeavor focused on the Floristic Diversity within the Shopian Forest Range in Jammu and Kashmir, India. The study region was categorized into three distinct altitudinal gradients: 1800m-2100m, 2100m-2400m, and 2400m-2700m. The outcomes of the investigation unveiled a total of 53 plant species belonging to 35 families. This assortment encompassed 9 tree species, 8 shrub species and 36 herb species. Among the families documented, Poaceae emerged as the prevailing family, represented by 7 species. Following closely were Pinaceae, Rosaceae, and Fabaceae, each contributing 4 species. In terms of distribution across altitude, the lower elevation exhibited the presence of 6 tree species, 7 shrub species and 28 herb species. Notably, the dominant tree species in this range was *Pinus wallichiana*. The mid-altitude range showcased a species richness of 7 tree species, 6 shrub species, and 25 herb species. Analyzing the data through the lens of the Shannon diversity index, a consistent declining trend was observed as one moved from lower to higher altitudes across all three life forms (trees, shrubs, and herbs). The intricate distribution and patterns of species richness were found to be influenced by various factors specific to each locality. These findings hold implications for

managerial decisions regarding the preservation and management of the studied area.

In a phytosociological analysis of pine forests in Indus Kohistan, Pakistan, Khan *et al*., (2016) found that *Cedrus deodara* exhibited the highest mean importance value across 28 different locations, followed by *Pinus wallichiana*. *Abies pindrow* ranked as the third most occurring species with a high mean importance value, while *Picea smithiana* achieved the fourth rank.

Pandey *et al*., (2016) conducted a study on forest structure, composition, and diversity along an altitudinal gradient in the Himalayas, Nepal. They identified Tsuga dumosa as the ecologically most important species in both the upper and lower sub-alpine zones, with a high importance value index (IVI) of 124.31. In the upper and lower temperate zones, *Quercus semecarpifolia* and *Lithocarpus elegans* emerged as the most important species, with IVIs of 66.64 and 46.39, respectively. The Shannon diversity index ranged from 1.10 to 2.34, with the highest value observed in the lower temperate zone.

Rana *et al*., (2015) assessed plant diversity, regeneration status, biomass, and carbon stock in a Central Himalayan Cypress forest. They identified a total of 36 plant species, including 7 trees, 8 shrubs, and 21 herbs. The tree density ranged from 460 to 600 trees per hectare, with a total basal area ranging from 19.11 to 58.20 square meters per hectare. The biomass of trees across all sites ranged between 178 and 431 tonnes per hectare, while carbon stock ranged from 89.07 to 206 tonnes per hectare. *Cupressus torulosa* showed fair regeneration, whereas other species were primarily represented by seedlings and saplings, indicating ongoing regeneration.

Rao *et al*., (2013) conducted phytosociological observations on tree species diversity in the tropical forests of Srikakulam district, Andhra Pradesh, India. They recorded a total of 129 tree species, belonging to 96 genera and 46 families. The predominant species included *Wrightia tinctoria, Lannea*

coromandelica, Diospyros sylvatica, Dalbergia paniculata, Chloroxylon swietenia, Cleistanthus collinus, Xylia xylocarpa, Alangium salvifolium, Cassia fistula, and *Morinda tinctoria*. The analysis of frequency classes indicated heterogeneity of vegetation, with the highest representation in class A (72 species), followed by classes B (26 species), C (13 species), D (7 species), and E (11 species).

Verma and Kapoor (2011) conducted a study to understand plant diversity along an altitudinal gradient ranging from 3000 m to 5000 m above mean sea level in the Ropa-Giavung valley of Kinnaur district, Himachal Pradesh. They recorded a total of 160 species belonging to 51 families and 119 genera. The dominant families in this study were Asteraceae, Polygonaceae, Rosaceae, and Ranunculaceae. The number of tree species varied across different elevations, with 12 tree species found at 3000-3500 m, including the dominant *Pinus gerardiana*. The shrub species comprised 20 species at 3000-3500 m and 15 species at 3500-4000 m, with *Rosa webbiana* and *Juniperus indica* being the dominant shrubs at their respective elevations. The herb species showed a higher diversity, with 83 species at 3000-3500 m, 46 species at 3500-4000 m, 44 species at 4000-4500 m, and 30 species at 4500-5000 m. Based on the Importance Value Index (IVI), *Ephedra gerardiana*, *Artemisia brevifolia*, *Bistorta affinis*, and *Potentilla argyrophylla* were identified as the dominant herbs across different elevational ranges. The index of diversity for herb species ranged from 2.98 to 3.97, indicating moderate to high diversity. The index of similarity between herb species at different altitudes was low, suggesting dissimilarity of species across elevations.

Shameem and Kangroo (2011) conducted a comparative assessment of edaphic factors and phytodiversity of herbaceous vegetation in the lower Dachigam National Park, Kashmir Himalaya, across different seasons. They reported higher Shannon diversity index and species richness during the summer season (3.66 and 7.92, respectively) in the mixed forest located inside the park's

official boundary, compared to the pasture land outside the boundary. However, the evenness index showed a similar trend with equal values at both sites (0.94). The study concluded that species diversity increased during the spring and summer seasons but declined during autumn and winter, attributed to various factors.

Pandey and Bajracharya (2010) examined the structural and floral composition of the vegetation in Sikre Village Development Committee (VDC) within Shivapuri National Park, Nepal. They employed systematic sampling techniques and identified 18 tree species from 13 families in the forest area. The dominant species were *Alnus nepalensis* (Uttis) and *Schima wallichii* (Chilaune). The major shrubs included *Hypericum uralum* (Yurilo), *Berberis aristata* (Chutro), and *Melastoma melabathricum* (Angeri). Among the herbaceous plants, *Phyllanthus freternus* (Bhui Amala), *Dryopteris filix-mas* (Unyu), and *Eupatorium adenophorum* (Banmara) were the dominant species. The above-ground biomass of tree species was estimated to be 4021.41 kg/ha, with *Castanopsis indica* (Dhalne katus) contributing significantly to the forest biomass. The study also assessed the resources demand and supply, revealing an annual deficit and calculated the carbon stock to be 2.01 t/ha. The Shannon Index of diversity was highest for trees (2.33), followed by shrubs (2.22) and herbs (2.17). The density of cut stumps and lopping indicated prominent anthropogenic pressure on the community forest.

Gairola *et al*., (2008) conducted a study in the Kumaun region of India at an altitude of 3000-3200 m. They found that three tree species, *Abies pindrow*, *Betula utilis* and *Acer caesium*, shared dominance with nearly equal Important Value Indices (IVIs) of 49.32, 48.32, and 45.54, respectively. These three species contributed significantly to the overall forest composition and structure in the study area.

Overall, the reviewed literature highlights the importance of phytosociological studies in understanding and protecting natural plant communities and biodiversity. Species diversity plays a crucial role in assessing the stability and sustainability of forest communities. Information on species composition, structure, and change is essential for the wise management of forests, considering their economic value, regeneration potential, and the conservation of biological diversity. These findings can aid in formulating effective conservation and management strategies for forest ecosystems, ensuring their long-term sustainability. By protecting and preserving natural plant communities and biodiversity, we can contribute to the overall well-being of our planet and maintain ecological balance for future generations. Further research in this field is warranted to enhance our knowledge and inform conservation efforts in a changing world.

2.3 Studies on propagation through seeds

Kheloufi *et al*., (2019) studied effect of moist stratification on seed germination in *Crataegus monogyna*. After collection of mature ripened fruits, their pulp was removed and seeds were left for 3 days to sundry. Four temperature regimes (treatments) viz. 4º C, 6.5º C, 10º C and 20º C were used and were replicated 4 times with 50 seeds incubated in a plastic container between two layers of moist sand at 15%. The findings of this experiment revealed that seed dormancy in hawthorn was broken most effectively by cold stratification at 4º C and under natural conditions with 76% and 67.5% germination , respectively.

Gokturk *et al*., (2017) studied seed properties of hawthorn and effects of sulfuric acid pretreatments on seed coat thickness. The thickness of seed coat of the thinnest part of seed changed between 0.82 (*Crataegus orientalis*) and 1.63 mm (*Crataegus pseudoheterophylla*). Species with the largest seed diameter were *Crataegus pontica* and *Crataegus pseudoheterophylla* (5.81 and 6.56 mm, respectively) and the species with smallest diameter was *Crataegus orientalis*

(3.48 mm). While the seed diameters pretreated with one hour sulfuric acid scarified by 4.68%, seed diameters pretreated with five hours sulfuric acid scarified by 10.04%. Investigations of this study revealed that the most affected seeds by acid scarification belong to *Crataegus orientalis* and the least affected seeds belong to *Crataegus pontica*. It has been also determined that even though *Crataegus orientalis* have the lowest seed weight (8.88 g) and the least seed size (3.47-6.36 mm) among the hawthorn species, it is one of the species which has highest (8.98%) moisture content**.**

Borkowsa (2008) conducted a study on breaking of seed dormancy in *Crataegus pedicellata*. Effects of various stratification and scarification treatments on seed dormancy breaking were studied in *Craetaegus pedicellata* (scarlet hawthorn). Fruits of hawthorn were collected in the month of October and the extracted seeds were cleaned and dried to moisture content of 9-12%. Findings of this study revealed that warm stratification followed by cold stratification was found most effective for breaking seed dormancy in *Craetaegus pedicellata* at 15~25°or 20~30°C (16+8 hrs or 24+24 hrs/cycle) for 16-20 weeks followed by cold stage at 3º C for 20 weeks. It was also observed that chemical scarification of seeds in 96% sulphuric acid for 2 hours followed by warm cold stratification at 20~30°/3°C with a short warm stage for 4 weeks also resulted in high emergence rate (85-93%). For seed dormancy breaking in *Craetaegus pedicellata,* it was recommended that chemical scarification of nutlets in 96% sulphuric acid for 2 hours followed by a short warm stratification for 4 weeks at 20~30°C (24+24 hrs.) and cold stratification at 3º C.

Borkowsa (2007) conducted a study on dormancy breaking, germination and seedling emergence from seeds of *Crataegus submollis*. Effects of various treatments of stratification on seed dormancy breaking was seen in *Craetaegus submollis* Sarg. The dormancy of seeds was broken by warm cold stratification of nutlets in a substrate or without any substrate at 15~25º/3ºC or 20~30°/3ºC, for 16-20 weeks, followed by cold stratification for 20 weeks. It was observed that

after stratification treatments emergence rate was equally high (ca 50%) at cyclically altering temperature of 3~15ºC and 3~20ºC for (16+8 hrs). It was also observed that chemical stratification of seeds in 96% sulphuric acid for at least 3 hours followed by warm cold stratification at 20~30º/3ºC, for 4 weeks also resulted in high emergence rate (58%).

Borkowska (2006) studied seed dormancy breaking in *Crataegus laevigata* (Hawthorn) species. Experiments were made to determine the conditions optimum for breaking of dormancy in *Crataegus* species. Seeds of hawthorn were subjected to stratification in a moist medium: 20~30°C/3°C for 16-20 weeks at 20~30°C (16+8 hrs or 24+24hrs), which was followed by 16-18 weeks at 3º C. Seeds were also subjected to chemical (20~30°C/3°C) scarification in concentrated sulphuric acid for 2-3 hours, followed by warm stratification at 27.5°C or 20 ~30°C for 4 weeks and cold stratification at 3ºC for 19-21 weeks. Results of this study revealed that stratified seeds showed vigorous germination in 3-5 weeks and at a high percentage at temperatures of 3~15°C or 3~20ºC (16+8 hrs) and all seedlings emerge in such conditions in 4-6 weeks after sowing. Highest germination and seedling emergence was found after warm followed by cold stratification at temperatures of about 20~30°C (16+8 hrs) for 20 weeks followed by cold phase at 3°C lasting for 16 weeks. Seedling emergence at temperature of 3~15°C (16+8 hrs) showed results (94%) and at 3~20°C (87%).

Borkowska (2002) studied seed dormancy breaking, germination and seedling emergence of the common hawthorn (*Crataegus monogyny* Jacq.). Seeds of *Crataegus monogyny* were subjected to stratification in a moist medium in three thermal regimes, 25°/3°C (16 weeks at 25°C followed by 15–18 weeks at 3°C, i.e .to the time when the first seedlings start to appear), 20~30°/3°C (16 weeks at 20~30°C (16+8 hrs/day) followed by 15–18 weeks at 3°C, i.e.to the time when first seedlings start to appear) and 20~30°/3°C (16weeks at 20~30°C (24+24 hrs) followed by 15–18 weeks at 3°C, i.e.to the time when first seedlings start to appear). Findings of this study revealed that the stratified seeds showed

vigorously germination in 3-5 weeks and at a high percentage at temperatures of 3~10°, 3~15°, 3~20° and 3~25°C, (16+8 hrs/day). Seedlings emerged at 3~20°C (16+8 hrs/day) in 4–6 weeks. It was also observed that storage of seeds for 1 year at –3°C after harvest and proper drying to the moisture content of 10% did not reduced their germination capacity. Stones scarification in concentrated sulphuric acid for 120 minutes followed by stratification at 3° C showed adverse effect on emergence of seed at temperature 3~20°C (16+8 hrs/day). Findings of this study also revealed that stratified seeds should be sown into the still cool soil at the end of March or the beginning of April because increased temperature induces the secondary dormancy in seeds**.**

Qrunfleh (1991) studied effects of various treatments of cold stratification (0, 20, 40, 60, 80, 100 and 120 days) on the content of endogenous abscisic acid and the germination of the hawthorn (*Craetaegus azarollus* L.). Findings of this study revealed that cold stratification reduced free and bound abscisic acid contents of the seed and their endocarps. Cold stratification (100 and 120 days) significantly improved germination percentage over the other treatments of stratification. The results further revealed that high germination percentage in hawthorn can be obtained by stratification of seeds for more than 120 days.

The reviewed studies focused on various aspects of seed germination and dormancy breaking in different hawthorn species. Strategies such as moist stratification, chemical scarification, and temperature regimes were employed to break seed dormancy and enhance germination rates. The findings provide valuable insights into the optimal conditions and treatments for promoting successful germination in hawthorn seeds, contributing to our understanding of hawthorn seed biology and cultivation practices.

2.4 Studies on propagation through cuttings

Rafeeq *et al*., (2020) conducted a study on effect of IBA on rooting and growth of *Morus alba* shoot cuttings in Kashmir Himalayas. Cuttings of Morus

species were treated with IBA at varying concentrations of (100, 150, 200, 250 and 300 ppm) for 24 hours. Sprouting percentage (95.55%), rooting percentage (68.88%), height of leading shoot (22.22 cm) and collar diameter of leading shoot (3.90 mm) was recorded highest in cuttings treated with IBA at concentration of 100 ppm while as sprouting percentage (65.00%), rooting percentage (13.33%), height of leading shoot (9.63 cm) and collar diameter of leading shoot (2.37 mm) was recorded lowest in cuttings treated with distilled water (control). Results of this study revealed that IBA at concentration of 100 ppm is the best plant growth regulator to be used for vegetative propagation of *Morus alba*.

Rasheid *et al*., (2018) conducted a study on Effect of IBA on rooting and seedling growth of *Ginkgo Biloba* L. stem cuttings under temperate Conditions of Kashmir. Softwood cuttings of both male and female trees of *Ginkgo biloba* were collected in February-March and were treated with different concentrations of Indole 3-butyric acid (IBA). Vegetative propagation of *Ginkgo biloba* stem cuttings revealed that 300ppm IBA have shown maximum sprouting (91.18%), survival (87.29%), rooting (74.77%), shoot length (21.07cm), collar diameter (5.93mm) in female trees. Results of the present investigation have led to the conclusion that female cutting performed better than male cuttings in terms of growth and biomass production.

Gopichand *et al*., (2017) studied standardization of different techniques for propagation of *Crataegus oxycantha* species. A field experiment was laid out in 2004 in CSIR-IHBT farm, by using different quantity of FYM and various spacing. Low growth in plant height was observed in first five years with higher dose of FYM, but in 2015 the significant height growth was recorded. From 2008 to 2015 all types of FYM applications produced statistically significant yield of seed production except in 2012 and 2014. The 22.50t/ha was the most statistically significant dose of FYM in relation to seed yield. The spacing did not produce any significant results for seed production. A vegetative propagation trial of *Craetaegus oxyacantha* was also laid out using semi hard stem cuttings and some

selected hormones (IAA, IBA, GA3 and Abscisic acid) with different concentrations. Statistically significant shoot sprouting (78.35%) was recorded when IBA of 1000 mg/L was used followed by 67.74% in case of 1500 mg/L of the same hormone. While lowest shoot sprouting (27.85%) was observed using 2000 mg/L of Abscisic acid. A statistically significant 5.67 cm and 5.33 cm shoot lengths were observed using 2000 mg/L of IAA and 1000 mg/L of IBA, respectively. In the case of shoot tillers 3.33 was recorded in 1500 mg/l. of IAA. Two new compounds and 9 known compounds were isolated from fruit extract.

Qaisar *et al.,* (2010) conducted experiment to see the effect of growth hormones IBA, IAA and NAA on rooting response of branch cuttings of *Morus alba* var. Gosherami. Different concentrations used were IBA, IAA and NAA with concentrations 100, 200, 300 & 400 ppm respectively. Distilled water was used as control. IBA (100 ppm), IAA (100ppm) and NAA (100 & 200 ppm) resulted in maximum rooting of 93.33%. Maximum root length was observed in IBA (200 ppm) as 127.3 cm, however maximum number (22) of roots per cutting was recorded in NAA (100 ppm).

Khan and Qaiser (2009) studied vegetative propagation of *Morus alba* var. Kanva through branch cuttings. The concentrations of growth hormones used were IBA 100, 200, 300 & 400 ppm, IAA 100, 200, 300 & 400 ppm and NAA 100, 200, 300 & 400 ppm besides Control (distilled water). Maximum rooting of 93.33% was recorded in IBA (100 ppm) & IAA (100 ppm) while as minimum rooting 20% was recorded in control (distilled water).

Singh and Bijmol (2000) studied the effects of various concentrations of IBA in hardwood cuttings of *Lagerstroemia indica*. Findings of this study revealed that IBA at concentration of 4000 ppm significantly increased root length, fresh and dry weights of roots and survival percentage, when compared to control (distilled water). Husen (2002) stated that the application of IBA at concentration of 2500 and 5000 ppm resulted significant improvement in percent

rooting, sprouting, mean number of roots per cutting and cutting length over the control in *Datura innoxia* shoot cuttings. But 5000 ppm IBA was more effective resulting in an increased rooting of 79.78 per cent while IBA 2500 ppm and control produced rooting percents of 62.66 and 29.87 respectively.

Aminah *et al*., (1995) reported that application of IBA auxin significantly increased the rate of root emergence in single node leafy stem cuttings of *Shorea leprosula* taken from 10 month old potted seedlings. A range of IBA doses (0, 20, 40, 60 and 80 µg IBA per cutting) were tested and 20 µg per cutting was found to be the best with 70% of cuttings rooted within 12 weeks. Higher doses resulted in less rooting success. IBA application also enhanced the number of roots developed on each cutting. The mean accumulated number of roots per rooted cutting in Week 10 on cuttings treated with 20, 40, 60, and 80 µg IBA was 5.05, 5.26, 4.82 and 4.80 respectively compared with 3.11 for cuttings treated with only a 50% ethanol and water mixture.

Overall, these studies collectively demonstrate the significant impact of growth hormones on rooting and growth in various plant species. The optimal concentration of these hormones varied among different plants, highlighting the importance of species-specific considerations when applying for vegetative propagation. These findings contribute to the understanding of the potential applications of IBA and NAA as a plant growth regulator in horticulture, forestry, and agriculture.

2.5 Studies on chemical profiling

Various studies have been conducted to explore the physicochemical characteristics and bioactive compounds present in different parts of hawthorn, such as fruits, flowers, leaves and extracts. Findings of various studies has been highlighted below, focusing on the physicochemical characterization, antioxidant activity, and phenolic compounds of hawthorn species.

Alirezalu *et al*., (2020) conducted a study on physicochemical characterization, antioxidant activity, and phenolic compounds of Hawthorn (Crataegus spp.) fruits species for potential use in food applications. Colour parameters, pH, total soluble solids, titratable acidity, total carotenoid, soluble carbohydrates, total phenols, flavonoid content, anti-oxidant activity and quantification of few individual phenolic compounds of 15 fruit samples of different hawthorn species. Findings of present study revealed that the total phenols, total flavonoid content, and antioxidant activity were in the range of 21.19–69.12 mg gallic acid equivalent (GAE)/g dry weight (dw), 2.44–6.08 mg quercetin equivalent (QUE)/g dw and 0.32–1.84 mmol Fe++/g dw, respectively. Hyperoside (0.87–2.94 mg/g dw), chlorogenic acid (0.06–1.16 mg/g dw), and iso-quercetin (0.24–1.59 mg/g dw) were found to be the most abundant phenolic compounds in the extracts of crataegus fruits.

Rocchetti *et al*., (2019) studied the biological and chemical profiles of three different hawthorn species (*Crataegus orientalis*, *Crataegus szovitsii* and *Crataegus tanacetifolia*). In this study, polyphenolic profiles were investigated by using ultra-high performance liquid chromatography-quadrupole time of flight mass spectrometry. Antioxidant activities of hawthorn species were investigated by using free radical scavenging, ferrous ion chelating, phosphomolybdenum and reducing power assays. Experimental findings of this study revealed that the methanolic extracts resulted the maximum radical scavenging and reducing activity in all test systems. In case of ferrous ion chelating assays, the decocted and infused extracts showed the highest activity. Results of this study also revealed that the tested extract showed remarkable inhibitory effects against tyrosinase and glucosidase, while all the extracts exhibited modest inhibition against α-amylase. Twig extracts used for study showed superior antioxidant and enzyme inhibitory activities. This study led to the conclusion that Crataegus species can be classified as potent bio-resource for high value phytochemicals.

Alirezalu *et al*., (2018) conducted a study on flavonoids profile and antioxidant activity in flowers and leaves of Crataegus species from different regions of Iran. The study was undertaken with the aim of determining the total quantity of flavonoids, phenols as well as to find out some information regarding HPLC quantification of some individual phenolic compounds (i.e. chlorogenic acid, vitexin 2"-O-rhamnoside, vitexin, rutin, hyperoside, quercetin, and isoquercetin) in leaves and flowers of 56 samples of different hawthorn species. The findings of the study revealed that the total amount of phenolics ranged from 7.21 to 87.73 mg GAE/g in dry weight of the plant while as the total amount of flavonoids varied among species as well as in different organs of the plant (2.27 to 17.40 mg/g dry weight). Vitexin, chlorogenic acid and vitexin2"-O-rhamnoside were found to be the most abundant phenolic compounds in the extracts of Crataegus leaves. In crataegus flowers, chlorogenic acid, hyperoside and rutin were found to be the most abundant phenolic compounds. Findings of this study also revealed that the antioxidant activity of Crataegus species exhibited that these species are having considerable antioxidant potential due to the presence of polyphenolic compounds. The antioxidant activity varied from species and among the different organs of the plant, ranging from 0.9 to 4.65 mmol Fe++/g DW plant, calculated through FRAP method**.**

Ozderi *et al*., (2016) investigated chemical properties of Hawthorn (*Crataegus* L.) taxa naturally distributed in western Anatolia part of Turkey. Results of this study revealed occurrence of various volatile oil components in hawthorn such as benzaldehyde (82.54%), butyraldehyde (38.27%) and E-2-hexenal (21.67%). Fatty acid composition was determined in with Gas Chromatography-Flame Ionization Detector (GCFID) using standard fatty acid mixture. Moisture values of hawthorn seeds varied between 14.49%-36.33%. 10 fatty acid compositions belonging to 7 hawthorn taxa were determined, the highest were linoleic (64.23%), oleic (39.36%) and palmitic acid (8.16%) respectively.

Nabavi *et al*., (2015) investigated polyphenolic composition of *Crataegus monogyna* Jacq. Four stereoisomers catechins and epicatechins are reported to be found both in the aerial and cell suspension cultures of *Crataegus monogyna*. *Craetaegus monogyna* is one of the most important edible plants of the family Rosaceae. Findings of this study revealed that hawthorn has various physiological and pharmacological activities due to the presence of variety of bioactive natural compounds**.**

Keser *et al*., (2014) conducted the investigation on some bioactive compounds and antioxidant properties of *Crataegus monogyna*. Total polyphenolic contents of the extracts was determined by Folin-ciocalteu reagent. Equivalent of phenolics was determined, which belong to 70.58-106.24 mg quercetin/1 g of dried weight of extract and 17.86-25.04 mg pyrocatechol/1 g of dried weight of extract. Different flavonoids including rutin, myricetin, apigenin, kampferol, quercetin and naringenin were identified by high performance liquid chromatography in the craetaegus species extracts. Findings of this study revealed that the aqueous and ethanol extracts of hawthorn fruits have highest activity in reducing power and metal chelating activity assays while as the aqueous flower extracts showed higher flavonoid content as compared to the extracts of hawthorn leaves. This study led to the conclusion that the antioxidant and pharmacological effects of Crataegus species is mainly attributed to the polyphenolic contents.

Wu *et al*., (2014) studied chemical constituents, pharmacology and potential applications in *Crataegus pinnatifida*. *Crataegus pinnatifida* is a species in family Rosaceae and is widely distributed throughout China. There are almost 150 compounds including flavonoids, triperpenoids, steroids, monoterpenoids, sesquiterpenoids, lignans, hydroxycinnamic acids, organic acids and nitrogen containing compounds which have been isolated and are found in *Crataegus pinnatifida*. The findings of this study revealed that different constituents and extracts of *Crataegus pinnatifida* have broad pharmacological effects with very low toxicity.

Wu *et al*., (2014) reported various flavonoids in *Crataegus pinnatifida,* such as flavones, flavanones, flavanonols, flavanols and polymers of flavanols. Flavones are a series of compounds whose aglycones are apigenin or luteolin. Various flavones which are found in *Crataegus pinnatifida* include apigenin, luteolin, orientin, iso-orientin, vitexin, vitexin rhamnoside, isovitexin, hyperoside, schaftoside, isoschaftoside, neoschaftoside, neoisoschaftoside, cratenacin and acetylvitexin. Different reported flavanols and flavanol polymers in *Crataegus pinnatifida* include (+)-catechin, (–)-Epicatechin, leucocyanidin ,proanthocyanidin A2, procyanidin B2, B4, B5, and trimers include procyanidin C1, procyanidin D1, epicatechin-(4β-6)-epicatechin-(4β-8)-epicatechin, epicatechin-(4β-8)-epicatechin-(4β-6)-epicatechin and procyanidin E1.

Kostic *et al*., (2012) investigated phenolic content, antioxidant and antimicrobial activities of *Crataegus oxyacantha* fruit extracts. They determined the total content of phenols, anthocyanins, flavonoids, antioxidant and antimicrobial activities of aqueous extracts of hawthorn fruits. Total phenols, flavonoids and anthocyannins content of the alcohol, hydroalcohol and aqueous extracts of Crataegus fruits was determined by using spectrophotometric methods. Antioxidant assay was based on the measurement of DPPH absorbance at 517 nm caused by the reaction of DPPH with the test sample. Antimicrobial activity of *Crataegus* species was evaluated by measuring the zone of inhibition against selected test microorganisms (*Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella abony*). Antifungal activity was tested against two organisms (*Aspergillus niger* and *Candida albicans*). Total phenol compounds of *Crataegus* fruit extracts varied from 2.12 to 30.63 mg GAE g-1 of fresh hawthorn fruit. The anthocyanins content of *Crataegus* fruit extracts ranged from 0.3207 to 3.168 mg of cyanidin-3-O-glucoside g-1 of fresh hawthorn fruit. Investigations of this study also revealed that fruit extracts of *Crataegus* species have high antioxidant activity with DPPH radical transformation value as high as 89.9% in the methanol water (50/50, v/v%)

extract. The extracts of ethanol exhibited antimicrobial activity against all test microorganisms except for *Bacillus subtilis* and *Staphylococcus aureus* and one species of fungi (*Aspergillus niger*). This study led to the conclusion that the fruit extracts of *Crataegus oxyacantha* L. can be used as natural antioxidant and antimicrobial preparations**.**

Kumar *et al*., (2012) reported that genus Crataegus of family Rosaceae have wide range of medicinal uses and is used for treatment of various ailments such as cardiovascular disorders, central nervous system, immune system, eyes, reproductive system, liver, kidney etc. *Crataegus oxyacantha* exhibits wide range of cytotoxic, gastroprotective, anti-inflammatory, anti-HIV and antimicrobial activities. The genus Crataegus is reported to have phytochemicals such as oligomeric procyanidins, flavonoids, triterpenes, polysaccharides, catechloamines etc**.**

Barros *et al*., (2010) investigated composition of fatty acids of flower and fruits in *Crataegus monogyna* Jacq. Findings of this study revealed highest content of linoleic acid in unripe fruits (58.5%), ripe fruits (17.53%), flower buds (15.64%), flowers (14.17%), ripened fruits (13.12%). Fatty acid composition was second highest in flower buds (36.95%), flowers (33.67%), unripe fruits (8.18%), ripened fruits (32.77%) and in un-ripened fruits (30.40%). Third fatty acid reported was γ linoiec acid, whose concentration varied from part to part. Highest content of γ linoiec acid was determined in flowers (29.51%) followed by flower buds (26.79%), unripe fruits (5.98%), ripened fruits (7.41%) and over ripened fruits (15.65%). Palmitic acid content was reported highest in over ripened fruits (15.52%), ripened fruits (13.73%), flowers (11.23%), flower buds (11.02%) and unripe fruits (10.61%).

Sahloul *et al*., (2009) investigated chemical composition of *Crataegus azarolus* L. fruits from 14 genotypes found in Tunisia. They collected fruits of hawthorn from 14 genotypes when fully ripened. Juice obtained from fruits was

analyzed for some chemical properties. The juice content [% (v/w)], pH, titratable acidity (g malic acid 100 ml–1), and formol index (ml NaOH 100 ml–1 juice), and the contents of total soluble solids (Brix), total sugars [(g 100 g–1 fresh fruit weight (FW)],reducing sugars (g 100 g–1 FW),and salts (mg 100 g–1 FW),were established as: 2.0 – 11.9%, 3.2 – 4.2, 0.9 – 1.9, 2.8 – 4.4, 16.3 – 21.5, 5.3 – 17.0, 5.8 – 7.9, and 0.6 – 0.7, respectively. It was also reported that fresh juice contained vitamin C (31.4 mg ascorbic acid 100 g–1 FW), calcium (285.6 – 399.1 mg 100 g–1 FW), sodium (30.4 – 43.8 mg 100 g–1 FW) and potassium. (138.5 – 169.2 mg 100 g–1 FW). Experimental findings of this study also revealed that the concentration of phenols ranged from 498.5- 1,477mg 100 g^{-1} fresh weight.

Verma *et al*., (2007) reported that hawthorn flowers, leaves and fruits contain different types of bioflavonoid like complexes. Major biflavonoids found in *Crataegus* species (hawthorn) include Vitexin, oligomeric procyanidins (OPC), hyperoside and quercetin. Besides these biflavonoids, hawthorn also contain other chemical constituents like, saponins, vitamin C, cardiotonic amines, purine derivatives (adenosine, adenine, guanine, caffeic acid, amygdalin), ursolic acid and triterpene acids**.**

Overall, the reviewed literature highlights the diverse pharmacological activities and chemical compositions of Crataegus species. The studies demonstrated the presence of various bioactive compounds, including phenolic compounds, flavonoids, fatty acids, and volatile oils, which contribute to the antioxidant, anti-inflammatory, cardioprotective, vasorelaxant, and hypolipidemic properties of Crataegus.

Chapter 3

MATERIALS AND METHODS

3.1. Study Area

3.2. To study phenology and population ecology of *Crataegus songarica*

3.2.1 Phenology of *Crataegus songarica*

3.2.1 Population ecology of *Crataegus songarica*

3.3. To study propagation of *Crataegus songarica* through seeds and cuttings

3.3.1 Propagation through seeds

3.3.2 Propagation through cuttings

3.4 Chemical profiling of *Crataegus songarica*

3.1 Study area

Phenological studies of *Crataegus songarica* were carried out at Malhar, Ganderbal. Studies on population ecology of *Crataegus songarica* were carried out in different Forest Divisions of Kashmir valley. Kashmir valley is located in the north-western extremity of India, between 33° North latitude and 75° East longitude. The valley is located in the northern most latitude of the country holds almost central position in the continent of Asia. Average altitude of Kashmir valley (valley zone) ranges between 1, 500 to 2, 300 m above sea level. The geographical expanse of Jammu and Kashmir UT is 42, 241 km^2 (Rafeeq *et al*., 2020).

Studies on propagation of *Crataegus songarica* were carried out at Field Nursery of Faculty of Forestry, SKUAST-Kashmir, Benehama. The experimental site Faculty of Forestry, SKUAST-Kashmir, Benehama village (Tehsil- Lar, District- Ganderbal) lies on the southern aspect at 34°16' 4" North latitude and

74°46' 31" East longitude. The study area is located at an elevation of 1, 783m (5850 feet) above the mean sea level. The study area has temperate climate experiencing four distinct seasons: a severe winter (December to Febuary), a cold spring (March to May), a mild summer (June to August) and a pleasant autumn (September to November). The site falls in a mid to high altitude characterized by hot summer and very cold winters. The average precipitation is 690-1150 mm most of which is received from December to April in the form of snow and rains. The climate is generally temperate type, winter is severe extending from December to March. The region faces a wide temperature range from -8° c in winter to maximum of 33° c in summer. Winter frost is common and medium to heavy snowfall is also witnessed.

Studies on chemical profiling of *Crataegus songarica* were carried out at ICAR CITH- Srinagar.

3.2 To study phenology and population ecology of *Crataegus songarica*

3.2.1 Phenology of *Crataegus songarica*

The phenology of crataegus species was studied to generate baseline data and were described in different phases of growth throughout the seasons. The following parameters were recorded:

A) Bud set
B) Bud burst/ break
C) Leaf initiation/flush
D) Flowering
E) Fruit Formation
F) Fruit/seed fall
G) Leaf tint
H) Leaf fall
I) Fruit fall

Sampling: 5 trees× 4 branches in each tree= 20 observations at weekly interval from February onwards.

Climatic data of District Ganderbal for the year 2021 and 2022 is shown in Annexure I.

3.2.2 Population ecology *Crataegus songarica*

The procedure of Ex- Post facto Research was applied. Surveys were conducted in different Forest Divisions of Kashmir Valley and the data was collected at each site where *Crataegus songarica* were found abundantly. Three quadrates were drawn at each site and the altitude was recorded at each site with the help of GPS.

Floristic data was analyzed in terms of frequency, density and basal area (Curtis and McIntosh, 1950). The relative values of frequency, density and basal area were calculated following Philips (1959). These values were combined to calculate the Importance Value Index (IVI) for each species, which represents their dominance and ecological success (Curtis, 1959). The quantitative analysis focused on determining the density, frequency and abundance of tree species, shrubs and herbs, following the approach by Curtis and McIntosh (1950).

Sampling:

Number of Forest divisions studied: 10

Number of sites studied in each Forest division: 10

Number of quadrates drawn at each site: 3

Number of quadrate drawn at each Forest division: 30

Total number of quadrates drawn in all the Forest divisions: 300

Observations recorded:

i. Number of individuals of species.

ii. Diameter (DBH for trees)

iii. Associate species

a) Density:

It was expressed as the number of plants per unit area. Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrates is divided by the total number of quadrants studied. Density was calculated by the following formula:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrate}}{\text{Total number of quadrants studied}} \text{ X } 100$$

b) Frequency (%)

This term refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrants in which the species occurred}}{\text{Total number of Quadrate studied}} \text{ X } 100$$

c) Basal area

Basal area is the term used to describe the average amount of an area occupied by tree stems. It is defined as the total cross sectional area of all stems in a stand measured at breast height and expressed as per unit of land area. It was calculated by using the formula:

$$Basal\ area = \frac{\pi D^2}{4}$$

Where 'D' is the DBH for trees at Breast Height.

Importance Value Index (IVI): The Importance Value Index (IVI) of the species was calculated as:

Importance Value Index = Relative Density + Relative Frequency + Relative Dominance

Relative density

Relative density is the study of numerical strength of a species in relation to the total number of individuals of all the species and was calculated as:

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$$

Relative frequency

The degree of dispersion of individual species in an area in relation to the number of all species occurred.

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

Relative basal area

Dominance of a species was determined by the value of the basal cover. Relative dominance is the coverage value of a species with respect to the sum of coverage of the rest of species in the area.

$$\text{Relative basal area} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

3.3 To study propagation of *Crataegus songarica* through seeds and cuttings

3.3.1 Propagation of *Crataegus songarica* through seeds

3.3.1.1 Morphometric characteristic of *Crataegus songarica* seeds

The seeds of *Crataegus songarica* were randomly collected in the month of September from trees located at different sites in the study area. After collection, following characteristics were studied

1. Seed weight (g)
2. Seed length (mm)
3. Seed diameter (mm)
4. Seed moisture.

3.3.1.2 Propagation of *Crataegus songarica*

The seeds of *Crataegus songarica* were randomly collected in the month of September from trees located at different sites in the study area. Different treatments were given to seeds i,e scarification with concentrated sulfuric acid (concentration 50%) alone for 1 hour, scarification with concentrated sulfuric acid for 1 hour and then subjected to cold stratification at about 4°C and mechanical scarification with hammer. The treated seeds were sown simultaneously in the Field and were replicated four times.

T0: Control

T1: Scarification with concentrated sulfuric acid (50%)

T2: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (40 days)

T3: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (50 days)

T4: Scarification with concentrated sulfuric acid (50%) + Cold stratification (60 days)

T5: Scarification with concentrated sulfuric acid (50%) + Cold stratification (70 days)

T6: Mechanical scarification with hammer

No. of replications : 03

Design : CRD

Observations recorded:

1. Germination percentage:

Germination percentage is the total number of seeds that germinated from a sample expressed as percentage. Germination percentage was calculated as per the guidelines of international Rules for Seed Testing (ISTA, 1966). Germination per cent was calculated using the formula suggested by Bonner (1983).

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

2. Germination energy (GE):

It is the per cent, by number, of seeds that germinated upto the peak of germination and was calculated using the formula suggested by Williams (1985).

$$\text{GE (\%)} = \frac{\text{Number of seeds germinated upto time of peak germination}}{\text{Total number of seeds sown}} \times 100$$

3. Germination value (GV):

It is the combined measurement of speed and declined point of germination represented by a single figure and was calculated using the formula suggested by Czabator (1962).

Germination value =Mean daily germination × Peak Value.

4. **Length of shoot (cm):**

It was measured with the help of a meter scale from leading shoot tip to the collar region of the seedling at the ground surface.

5. Length of root (cm):

The length of tap root was recorded in centimeters using measuring scale by placing it horizontally on the ground.

6. Average number of roots:

The number of roots within each treatment was counted and expressed as average number of roots per cutting.

7. Vigour index:

It reflects the health of the seedling produced. It takes into account the germination percent and the total seedling length. Vigour index was calculated by using formula suggested by Abdul Baki and Anderson (1973).

Vigour index = Germination percent × Total mean seedling length

8. Leaf area (cm^2): It was measured by using leaf area meter.

3.3.2 Propagation of *Crataegus songarica* through cuttings:

Cutting collection and Planting operations:

Cuttings of *Crataegus songarica* were collected from actively growing plant located in the study area. Hardwood stem cuttings were collected in the month of February.

Preparation of IBA solution:

The calculated amount of IBA (Indole-3- butyric acid) was dissolved thoroughly in small quantity of ethyl alcohol (10- 15 ml) so that it can dissolve properly. The mixture was continuously stirred with a glass rod to form homogenous solution and to reduce precipitation. Then required volume was

made by adding distilled water to have the stock solution of desired concentration. The stock solution was further diluted to make working solution of desired concentrations. Fresh stock solution was prepared each time for treating the cuttings. Different IBA and NAA treatments (12) were given to the cuttings and were replicated four times as follow:

T_0 : Control (water)

T_1 : IBA@ 1000 ppm

T_2 : IBA@ 2000 ppm

T_3 : IBA@ 3000 ppm

T_4 : IBA@ 4000 ppm

T5 : IBA@5000 ppm

T6 : IBA@6000 ppm

T7 : NAA@ 1000 ppm

T8 : NAA@ 2000 ppm

T9 : NAA@ 3000 ppm

T10 : NAA@ 4000 ppm

T11 : NAA@5000 ppm

T12 : NAA@6000 ppm

The experiment was laid in polybags with soil, sand, FYM (2:1:1) as potting media at Faculty of Forestry Benihama/ Watlar Nursery of SKUAST-Kashmir.

Number of Treatments = 13

Number of cuttings per treatment = 20

Number of Replications = 3

Total number of Cuttings = 780

Experimental design = CRD

The observations were taken with regard to:-

(1) Sprouting percentage: The total number of cuttings which sprout under each treatment were counted and were expressed as sprouting percentage.

(2) Rooting percentage: The total number of cuttings within each treatment, that showed the formation of roots were counted and were expressed in percentage at the end of the growing season.

(3) Average number of roots per cutting: The number of roots within each treatment were counted and were expressed as average number of roots per cutting.

(4) Average root length (cm): The length of root were recorded in centimeters with the help of measuring scale after uprooting at the end of the growing season.

(5) Collar diameter of the leading shoot (mm): It was measured for five randomly selected rooted cuttings within each treatment with the help of digital vernier calliper and were expressed in milimeter.

(6) Leaf area (cm^2): It was measured by using leaf area meter.

(7) Average plant height (cm): It was measured in centimeters with the help of measuring scale at the end of the growing season.

3.4 To study the chemical profiling of *Crataegus songarica*

Plant samples

Leaves and fruit specimens were collected randomly from wild growing *Crataegus songarica* from different sites located in the study area. The fruits and leaves were dried at room temperature after sampling and then stored in dry and cool conditions until analysis (Alirezalu *et al*., 2020; Alirezalu *et al*., 2018). Different locations from which samples were collected is given below.

Sites	Altitude (m)	Latitude	Longitude
Malhar Ganderbal	1850	34.33° N	74.46° E
Babareshi, Gulmarg	2050	34.05° N	74.38° E
Dachigam National Park, Srinagar	1800	34.07° N	74.61° E
Ajas, Bandipora	1750	34.37° N	74.67° E
Shikergah, Tral	1900	33.86° N	75.10° E

Preparation of Fruit Extracts

Fruits of *Crataegus songarica* were dried using convection oven at 45±2º C for 24 h and ground to homogenized particle size before extraction. Powdered samples (1 g) were than extracted using methanol/water (80:20, 25 mL), then they were filtered (Alirezalu *et al*., 2020)

Preparation of the leave extracts

Leaves of *Crataegus songarica* were dried at room temperature and were grounded to homogenized particle size before extraction. Powdered samples (1 g) were extracted using methanol/water (80 %, v/v), then they were filtered (Alirezalu *et al*., 2018).

OBSERVATIONS RECOREDED

(1) Total soluble solids (TSS)

Total soluble solids (TSS) of fruits, were expressed as % malic acid, of fruits and were measured by a handheld refractometer and titratable acidity (TA)

by titration of fruit juice with 0.1 N NaOH to pH 8.3 and data was expressed as a percentage of malic acid (Alirezalu *et al.*, 2020; Alirezalu *et al.*, 2018).

(2) Total phenolic content

Total phenolic content were assayed according to Singleton *et al*., (1999). The total content of phenolic compounds were determined by the Folin–Ciocalteu method. The extracted samples (0.5 ml of different dilutions) were mixed with Folin Ciocalteu reagent (5 ml, 1:10 diluted with distilled water) for 5 min and aqueous Na_2CO_3 (4 ml, 1 M) was added to it. The mixture were allowed to stand for 15 min and the phenolics was determined by spectrophotometer at 765 nm.

(3) Total flavonoid content

The total flavonoid content of the leaves and fruit extracts were determined by using aluminum chloride colorimetric method with slight modification using quercetin as standard and the results were expressed as mg of quercetin equivalents per g dry weight of the plant (mg g-1 DW) (Chang *et al*., 2002).

(4) Antioxidant activity

The antioxidant activity was calculated in mmol Fe++/g DW by using ferric-reducing antioxidant power (FRAP) assay (Zugic *et al*., 2014).

Chapter 4

EXPERIMENTAL FINDINGS

This chapter deals with the research findings of the present investigations entitled **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** as per the methodology given in the preceding chapter. The results obtained in the present investigations have been presented objective wise as under:

4.1 To study phenology and population ecology of *Crataegus songarica*

4.1.1 Phenology of *Crataegus songarica*

4.1.2 Population ecology of *Crataegus songarica*

4.2 To study propagation of *Crataegus songarica* through seeds and cuttings

4.2.1 Propagation of *Crataegus songarica* through seeds:

4.2.2 Propagation of *Crataegus songarica* through cuttings

4.3 To study the chemical profiling of *Crataegus songarica*

4.1 To study phenology and population ecology of *Crataegus songarica*

4.1.1 Phenology of *Crataegus songarica*

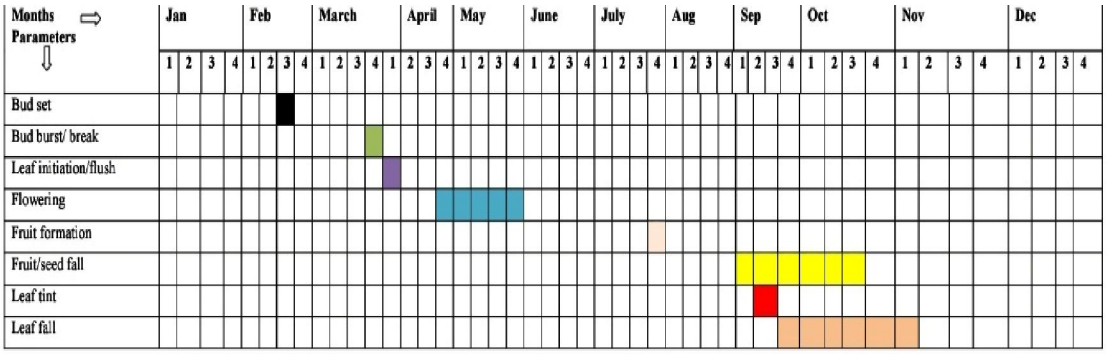
The preliminary information regarding the different phenophases of Hawthorn, *Crataegus songarica* in the Kashmir Himalayas is presented in table 1 and figure 1. The observations for the year 2021 indicate that bud set began in the third week of February, followed by bud bursting in the fourth week of March. By the first week of April, the leaves were fully open. Flowering started in the fourth week of April and continued until the fourth week of May, with the peak occurring in the second week of May. Fruit initiation was observed in the fourth week of July, while fruit fall started in the second week of September and lasted until the third week of October. Leaf tint was observed during the third week of

September, and leaf fall commenced in the fourth week of September, continuing until the first week of November. Investigations revealed that the entire phenophase cycle of *Crataegus songarica* lasted 9 months and 3 weeks (Plate I).

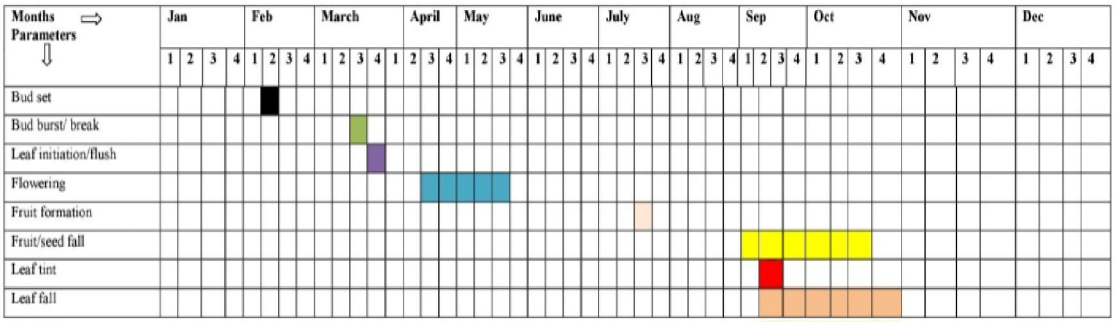
The observations for the year 2022 indicate that bud set began in the second week of February, followed by bud bursting in the 3rd week of March. By the fourth week of March, the leaves were fully open. Flowering started in the third week of April and continued until the third week of May, with the peak occurring in the first week of May. Fruiting initiation was observed in the third week of July, while fruit fall started in the first week of September and lasted until the third week of October. Leaf tint was observed during the second week of September, and leaf fall commenced in the third week of September, continuing until the fourth week of October. Investigations revealed that the entire phenophase cycle of *Crataegus songarica* lasted 9 months and 3 weeks.

Table 1: Phenophases of *Crataegus songarica* in Kashmir Himalayas

Phenological Characteristic		Year 2021	Year 2022
Bud set		February (3^{rd} week)	February (2^{nd} week)
Bud burst/ break		March (4^{th} week)	March (3^{rd} week)
Leaf initiation/flush		April (1^{st} week)	March (4^{th} week)
Flowering	**Initiation**	April (4^{th} week)	April (3^{rd} week)
	Peak	May (2^{nd} week)	May (1^{st} week)
	Completion	May (4^{th} week)	May (3^{rd} week)
Fruit Formation/Seed set		July (4^{th} week)	July (3^{rd} week)
Fruit/seed fall	**Initiation**	September (2^{nd} week)	September (1^{st} week)
	Completion	October (3^{rd} week)	October (3^{rd} week)
Leaf tint		September (3^{rd} week)	September (2^{nd} week)
Leaf fall	**Initiation**	September (4^{th} week)	September (3^{rd} week)
	Completion	November (1^{st} week)	October (4^{th} week)



(A)



(B)

Fig 1: Phenophases of *Crataegus songarica* A. 2021, B. 2022

Bud set

Bud burst

Leaf initiation

Flowering

Fruit formation

Fruit/seed fall

Leaf tint

Leaf fall

Plate I: Phenophases of *Crataegus songarica*

4.1.2 Population ecology of *Crataegus songarica*

The phytosociological parameters such as density (D), frequency (F), basal area (BA), relative density (RD), relative frequency (RF), relative basal area (RBA), important value index (IVI) and Shannon Weiner index (H') have been shown in table 2 to table 34 for different Forest Divisions of Kashmir.

Associate Species of Hawthorn, *Crataegus songarica*

In the forests of Kashmir Himalayas, a total of 34 species were observed to grow alongside *Crataegus songarica* (Table 2). Among these species, there were 11 trees (Plate II), 6 shrubs (Plate III), and 16 herbs (Plate IV). These species belonged to 23 families, with Pinaceae, Fabaceae, Rosaceae, and Asteraceae being the dominant families, each comprising 3 species. Additionally, Cannabaceae, Moraceae, Berberidaceae, and Poaceae were represented by 2 species each. Simaroubaceae, Sapindaceae, Juglandaceae, Ulmaceae, Hamamelidaceae, Sambucaceae, Caprifoliaceae, Liliaceae, Hypericaceae, Lamiaceae, Malvaceae, Polygonaceae, Urticaceae, and Violaceae were represented by 1 species each. The table 2 and table 3 presents information about the common name, family, local name and presence absence of species across various Forest divisions in the Kashmir Himalayas.

Figure 2 shows presence and absence of species in different Forest divisions. Figure 3 shows IVI of *Crataegus songarica* in different Forest divisions of Kashmir Himalayas.

Aesculus indica *Cedrus deodara* *Ailanthus altissima*

Juglanas regia *Robinia pseudoacacia* *Pinus walliachiana*

Morus alba *Morus nigra*

Plate II: Tress species identified in the study area

Crataegus songarica *Rosa webbiana* *Sambucus wightiana*

Indigofera heterantha *Vibernum grandiflorum* *Berberis lyceum*

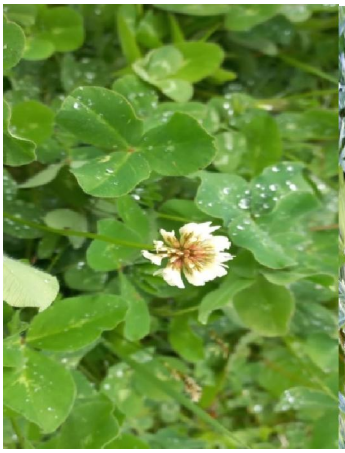
Parrotia jacquemontiana

Plate III: Shrub species identified in the Study Area

Fragaria vesca

Cynodon dactylon

Viola odorata



Trifolium repens

Artimesia absinthium

Fritillaria imperialis

Malva neglecta

Hypericum perforatum

Plate IV: Herb species identified in the Study Area

Table 2: Floristic diversity in different Forest Divisions of Kashmir Himalayas

S.No.	Scientific Name	Family	Common Name	Local Name	Life form
1	*Ailanthus altissima*	Simaroubaceae	Tree of Heaven	Alamtees	Tree
2	*Aesculus indica*	Sapindaceae	Horse chestnut	Han doon	Tree
3	*Abies pindrow*	Pinaceae	Fir	Budlu	Tree
4	*Cedrus deodara*	Pinaceae	Himalayan cedar	Deodar	Tree
5	*Celtis australis*	Cannabaceae	European nettle tree	Brimji	Tree
6	*Juglans regia*	Juglandaceae	Walnut	Doon	Tree
7	*Morus nigra*	Moraceae	Black mulberry	Tul	Tree
8	*Morus alba*	Moraceae	White mulberry	Shahtoot	Tree
9	*Robinia pseudoacacia*	Fabaceae	Black locust	Kikar	Tree
10	*Pinus walliachiana*	Pinaceae	Kail	Kayur	Tree
11	*Ulmus villosa*	Ulmaceae	Elm	Bren	Tree

12	*Berberis lycium*	Berberidaceae	Berberis	Kaw dach	Shrub
13	*Crataegus songarica*	Rosaceae	Hawthorn	Ringkul	Shrub
14	*Parrotia jacquemontiana*	Hamamelidaceae	Parrotia	Poh	Shrub
15	*Rosa webbiana*	Rosaceae	Webb's rose	Kashur Gulab	Shrub
16	*Sambucus wightiana*	Sambucaceae	Elder	Fhakee	Shrub
17	*Vibernum grandiflorum*	Caprifoliaceae	Grand viburnum	Kul maach	Shrub
18	*Indigofera heterantha*	Fabaceae	Himalayan indigo	Kots	Shrub
19	*Artimesia absinthium*	Asteraceae	Worm wood	Tethwen	Herb
20	*Cynodon dactylon*	Poaceae	Couch grass	Dramun	Herb
21	*Cannabis sativa*	Cannabaceae	Hemp	Bhang	Herb
22	*Conyza canadensis*	Asteraceae	Canadian fleabane	Butter weed	Herb
23	*Dactylis glomerata*	Poaceae	Orchard grass	....	Herb
24	*Fragaria vesca*	Rosaceae	Himalayan strawberry	Ringrech	Herb
25	*Fritillaria imperialis*	Liliaceae	Kaiser's Crown	....	Herb
26	*Hypericum perforatum*	Hypericaceae	Perforate St Johns Wort	....	Herb
27	*Mentha spicata*	Lamiaceae	Spear mint	Pudna	Herb

28	*Malva neglecta*	Malvaceae	Common mallow	Kashir sochel	Herb
29	*Podophyllum hexandrum*	Berberidaceae	Himalayan may apple	Wan wagun	Herb
30	*Rumex nepalensis*	Polygonaceae	Common Sorrel	Abej	Herb
31	*Trifolium repens*	Fabaceae	White clover	Safed batakh leunt	Herb
32	*Taraxacum officinale*	Asteraceae	Common dandlion	Hand	Herb
33	*Urtica dioica*	Urticaceae	Stinging nettle	Soi	Herb
34	*Viola odorata*	Violaceae	Wood violet	Bunafshaa	Herb

Table 3: Presence and Absence of Tree, Herb and Shrub species in Forest Divisions of Kashmir Himalayas

Scientific Name	Family	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Ailanthus altissima	Simaroubaceae	+	-	+	-	-	+	-	+	+	-
Aesculus indica	Sapindaceae	+	+	+	+	-	+	+	-	+	+
Abies pindrow	Pinaceae	-	-	+	-	-	+	-	+	+	
Cedrus deodara	Pinaceae	+	+	-	+	+	-	+	+	+	+
Celtis australis	Cannabaceae	+	-	-	+	-	-	-	-	-	+
Juglans regia	Juglandaceae	+	+	+	+	+	+	+	-	+	+
Morus nigra	Moraceae	+	+	+	+	+	-	-	-	-	+
Morus alba	Moraceae	-	+	-	-	-	-	-	+	+	+
Robinia pseudoacacia	Fabaceae	+	+	+	+	+	+	+	+	-	+
Pinus walliachiana	Pinaceae	-	-	+		+	+	+	+	+	+
Ulmus villosa	Ulmaceae	-	-	-	+	-	-	+	-	-	-
Berberis lycium	Berberidaceae	+	+	+	+	+	+	-	+	-	+
Crataegus songarica	Rosaceae	+	+	+	+	+	+	+	+	+	+

Parrotia jacquemontiana	Hamamelidaceae	+	+	+	+	+	+	+	+	+	+
Rosa webbiana	Rosaceae	+	+	-	+	-	-	-	+	-	-
Sambucus wightiana	Sambucaceae	+	-	+	-	-	-	-	-	-	-
Vibernum grandiflorum	Caprifoliaceae	+	+	+	+	+	+	+	+	+	+
Indigofera heterantha	Fabaceae	+	+	+	+	+	+	+	+	+	+
Artimesia absinthium	Asteraceae	+	+	+	-	-	+	+	-	-	+
Cynodon dactylon	Poaceae	+	+	+	+	+	+	+	+	+	+
Cannabis sativa	Cannabaceae	+	-	+	-	-	+	+	+	+	-
Conyza canadensis	Asteraceae	-	-	-	+	-	-	-	+	+	-
Dactylis glomerata	Poaceae	+	+	+	+	+	+	+	+	+	+
Fragaria vesca	Rosaceae	+	-	+	+	+	+	+	+	-	+
Fritillaria imperialis	Liliaceae	-	+	+	+	+	+	+	+	+	+
Hypericum perforatum	Hypericaceae	+	+	-	+	+	+	-	+	+	+
Mentha spicata	Lamiaceae	+	-	+	+	+	+	-	+	-	+
Malva neglecta	Malvaceae	+	+	+	+	+	+	-	+	+	+
Podophyllum hexandrum	Berberidaceae	+	-	-	+	+	+	+	-	-	-

Rumex nepalensis	Polygonaceae	+	+	+	+	+	+	+	-	+	+
Trifolium repens	Fabaceae	+	+	+	+	+	+	+	+	+	-
Taraxacum officinale	Asteraceae	+	+	+	+	+	+	+	+	+	+
Urtica dioica	Urticaceae	+	+	+	+	+	+	+	+	+	+
Viola odorata	Violaceae	+	+	+	+	+	+	+	+	+	+

D1: Sindh Forest Division; D2: Bandipora Forest Division; D3: Budgam Forest Division; D4: Tangmarg Forest Division; D5: Shopain Forest Division; D6: Anantnag Forest Division; D7: Langate Forest Division; D8: Kamraj Forest Division; D9: Kehmil Forest Division; D10: Baramulla Forest Division

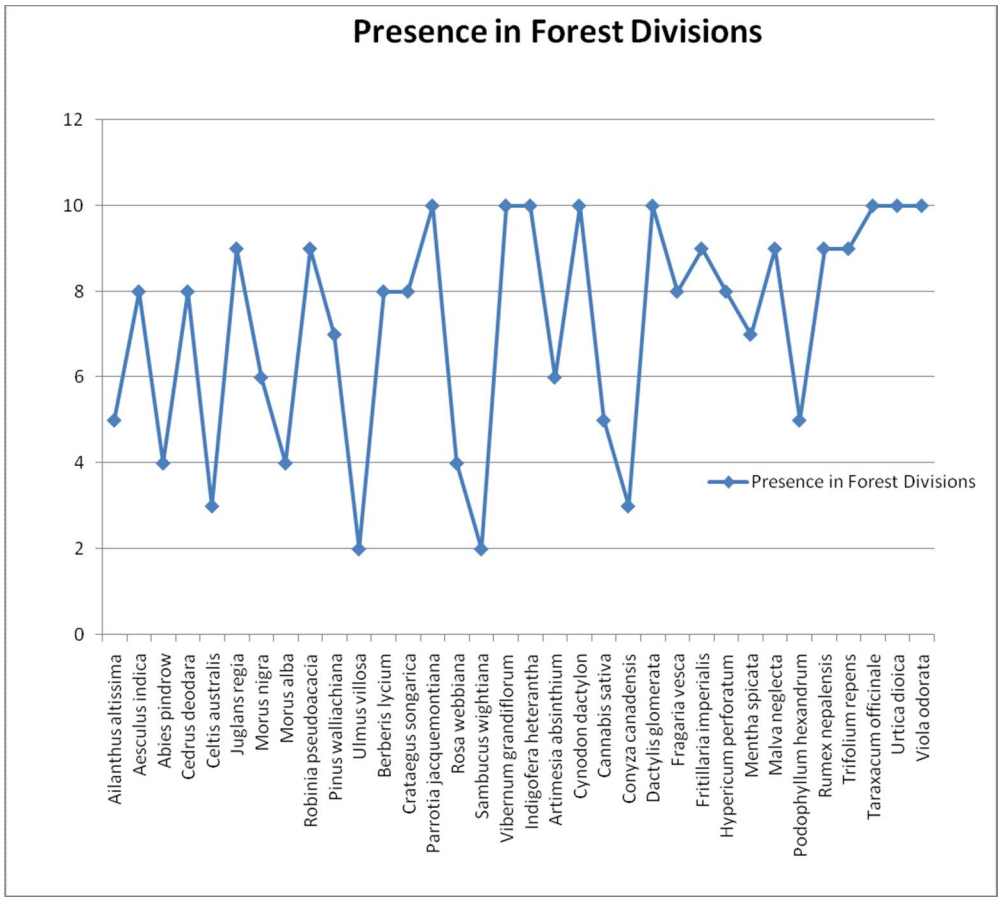


Fig 2: Presence and Absence of Associate species of *Crataegus songarica* in Forest Divisions of Kashmir Himalayas

Phytosociological attributes of plant species

Sindh Forest Division (1700 to 1950 m)

The data presented in the tables 4, 5 and 6 pertaining to the Sindh Forest Division reveals the presence of seven tree species, seven shrub species, and 14 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 82.58, followed by *Juglans regia* (45.19), *Ailanthus altissima* (40.07), *Robinia pseudoacacia* (37.37), *Aesculus indica* (33.34) and *Celtis australis* (31.61). The lowest IVI was observed for *Morus nigra* (29.84) (Table 4).

Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 61.79, followed by *Vibernum grandiflorum* (48.45), *Parrotia jacquemontiana* (43.56), *Rosa webbiana* (39.61), *Indigofera heterantha* (36.83), and *Sambucus wightiana* (35.68). The lowest IVI was observed for *Berberis lyceum* (34.18) (Table 5).

Among the Herb species, the maximum IVI was observed for *Cynodon dactylon* (32.24), followed by *Fragaria vesca* (31.06) and *Malva neglecta* (24.10) (Table 6). The lowest IVI was observed for *Podophyllum hexandrum* (13.00).

Bandipora Forest Division (1800 to 2050 m)

The data presented in the tables 7, 8 and 9 pertaining to the Bandipora Forest Division reveals the presence of six tree species, five shrub species, and 11 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 100.99, followed by *Juglans regia* (50.12), *Robinia pseudoacacia* (45.56), *Aesculus indica* (38.51) and *Morus nigra* (33.39. The lowest IVI was observed for *Morus alba* (31.45) (Table 7).

Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 69.69, followed by *Parrotia*

jacquemontiana (50.01), *Rosa webbiana* (49.55), *Indigofera heterantha* (47.96) and *Vibernum grandiflorum* (42.62). The lowest IVI was observed for *Berberis lyceum* (40.17) (Table 8).

Among the Herb species, the maximum IVI was observed for *Malva neglecta* (33.33), followed by *Taraxacum officinale* (32.17), *Cynodon dactylon* (31.68) and *Trifolium repens* (30.59) (Table 9). The lowest IVI was observed for *Viola odorata* (21.11).

Budgam Forest Division (1750 to 2000 m)

The data presented in the tables 10, 11 and 12 pertaining to the Budgam Forest Division reveals the presence of seven tree species, six shrub species, and 13 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Pinus walliachiana* with a value of 78.74, followed by *Abies pindrow* (65.35), *Juglans regia* (34.52), *Aesculus indica* (33.01), *Morus nigra* (30.89), *Ailanthus altissima* (30.09). The lowest IVI was observed for *Robinia pseudoacacia* (27.80) (Table 10).

Among the shrub species in the area, *Vibernum grandiflorum* was the dominant species with an IVI value of 58.62, followed by *Crataegus songarica* (55.53), *Parrotia jacquemontiana* (53.52), *Indigofera heterantha* (48.88) and *Sambucus wightiana* (41.94). The lowest IVI was observed for *Berberis lyceum* (41.51) (Table 11).

Among the Herb species, the maximum IVI was observed for *Fragaria vesca* (34.89), followed by *Trifolium repens* (26.90), *Mentha spicata* (25.76) and *Artimesia absinthium* (25.33) . The lowest IVI was observed for *Viola odorata* (16.50) (Table 12).

Table 4: Floristic composition and phytosociological attributes of tree species at Sindh Forest Division (1700 to 1950 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Ailanthus altissima	130.43	53.33	6.23	14.45	15.68	9.94	40.07
Aesculus indica	116.33	46.66	4.21	12.90	13.72	6.72	33.34
Cedrus deodara	170.92	70.00	26.96	18.94	20.60	43.04	82.58
Celtis australis	107.92	43.33	4.32	11.96	12.75	6.90	31.61
Juglans regia	112.24	40.00	13.14	12.44	11.76	20.99	45.19
Morus nigra	97.93	36.66	5.13	10.85	10.79	8.20	29.84
Robinia pseudoacacia	166.67	50.00	2.64	18.46	14.70	4.21	37.37
Total	**902.44**	**339.98**	**62.63**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**128.92**	**48.56**	**8.94**	**14.28**	**14.28**	**14.28**	**42.85**
S.E±	**10.94**	**4.17**	**3.26**	**1.21**	**1.22**	**5.21**	**6.91**

Table 5: Floristic composition and phytosociological attributes of Shrub species at Sindh Forest Division (1700 to 1950 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	366.63	43.33	1.33	14.37	10.83	8.98	34.18
Crataegus songarica	398.94	73.33	4.12	15.64	18.33	27.82	61.79
Parrotia jacquemontiana	373.91	50.00	2.43	14.66	12.5	16.40	43.56
Rosa weibaana	298.94	56.66	2.03	11.72	14.18	13.71	39.61
Sambucus wightiana	288.31	40.00	2.13	11.30	10.00	14.38	35.68
Vibernum grandiflorum	436.31	76.66	1.79	17.10	19.16	12.09	48.35
Indigofera heterantha	387.94	60.00	0.98	15.21	15.00	6.62	36.83
Total	**2550.98**	**399.98**	**14.81**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**364.42**	**57.14**	**2.11**	**26.51**	**14.28**	**14.28**	**42.85**
S.E±	**20.17**	**5.31**	**0.38**	**0.79**	**1.32**	**2.58**	**3.66**

Table 6: Floristic composition and phytosociological attributes of Herb species at Sindh Forest Division(1700 to 1950 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency(%)	Relative Basal Area (%)	IVI
Artimesia absinthium	5.98	73.33	1.77	7.90	8.59	6.34	22.83
Cynodon dactylon	8.93	83.33	2.98	11.80	9.77	10.67	32.24
Cannabis sativa	4.44	60.00	1.96	5.87	7.03	7.02	19.92
Dactylis glomerata	4.26	66.66	1.15	5.63	7.81	4.12	17.56
Fragaria vesca	7.73	76.66	3.31	10.21	8.99	11.86	31.06
Hypericum perforatum	3.96	53.33	1.87	5.23	6.25	6.70	18.18
Mentha spicata	5.31	60.00	2.24	7.01	7.03	8.02	22.06
Malva neglecta	6.67	70.00	1.98	8.81	8.20	7.09	24.10
Podophyllum hexandrum	2.31	43.33	1.36	3.05	5.08	4.87	13.00
Rumex nepalensis	4.56	46.66	1.77	6.02	5.47	6.34	17.83
Trifolium repens	6.66	53.33	2.33	8.80	6.25	8.35	23.40
Taraxacum officinale	6.12	70.00	1.53	8.08	8.20	5.48	21.76
Urtica dioica	4.41	56.66	2.33	5.83	6.64	8.34	20.81
Viola odorata	4.36	40.00	1.34	5.76	4.69	4.80	15.25
Total	**75.70**	**853.29**	**27.92**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.40**	**60.94**	**1.99**	**7.14**	**7.14**	**7.14**	**21.42**
S.E±	**0.46**	**3.46**	**0.16**	**0.60**	**0.40**	**0.58**	**1.43**

Table 7: Floristic composition and phytosociological attributes of Tree species at Bandipora Forest Division (1800 to 2050 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Aesculus indica	120.66	50.00	4.31	15.45	16.14	6.92	38.51
Cedrus deodara	210.93	73.33	31.24	27.01	23.69	50.29	100.99
Juglans regia	114.62	46.66	12.64	14.68	15.07	20.35	50.10
Morus nigra	94.31	40.00	5.21	12.08	12.92	8.39	33.39
Morus alba	83.46	36.33	5.62	10.68	11.73	9.04	31.45
Robinia pseudoacacia	156.93	63.33	3.11	20.10	20.45	5.01	45.56
Total	**780.91**	**309.65**	**62.13**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**130.15**	**51.60**	**10.35**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**17.75**	**5.35**	**4.06**	**2.27**	**1.73**	**6.55**	**9.81**

Table 8: Floristic composition and phytosociological attributes of Shrub species at Bandipora Forest Division (1800 to 2050 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	321.94	53.33	1.39	16.28	13.11	10.78	40.17
Crataegus songarica	336.92	76.66	4.36	17.04	18.85	33.80	69.69
Parrotia jacquemontiana	356.23	63.33	2.12	18.01	15.57	16.43	50.01
Rosa weibaana	361.24	60.00	2.13	18.27	14.76	16.52	49.55
Vibernum grandiflorum	312.93	80.00	0.92	15.82	19.67	7.13	42.62
Indigofera heterantha	288.41	73.33	1.98	14.58	18.04	15.34	47.96
Total	**1977.67**	**406.65**	**12.90**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**329.61**	**67.77**	**2.15**	16.66	**16.66**	**16.66**	**50.00**
S.E±	**10.41**	**3.95**	**0.44**	**0.52**	**0.97**	**3.46**	**3.93**

Table 9: Floristic composition and phytosociological attributes of Herb species at Bandipora Forest Division (1800 to 2050 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Artimesia absinthium	5.82	66.66	1.80	9.81	9.80	8.42	28.03
Cynodon dactylon	6.23	76.66	2.12	10.50	11.27	9.91	31.68
Dactylis glomerata	4.21	70.00	1.83	7.10	10.29	8.56	25.95
Fritillaria imperialis	3.63	46.66	2.39	6.12	6.87	11.17	24.16
Hypericum perforatum	4.69	40.00	1.76	7.91	5.88	8.23	22.02
Malva neglecta	7.23	76.66	2.11	12.19	11.28	9.86	33.33
Rumex nepalensis	4.69	50.00	1.83	7.91	7.35	8.55	23.81
Trifolium repens	6.69	63.33	2.14	11.28	9.31	10.00	30.59
Taraxacum officinale	7.23	76.66	1.86	12.19	11.28	8.70	32.17
Urtica dioica	4.46	60.00	2.31	7.52	8.83	10.80	27.15
Viola odorata	4.43	53.33	1.24	7.47	7.84	5.80	21.11
Total	**59.31**	**679.96**	**21.39**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.39**	**61.81**	**1.94**	**9.09**	**9.09**	**9.09**	**27.27**
S.E±	**0.38**	**3.90**	**0.09**	**0.65**	**0.57**	**0.44**	**1.28**

Table 10: Floristic composition and phytosociological attributes of Tree species at Budgam Forest Division (1750 to 2000 m)

Trees	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Ailanthus altissima	124.62	43.33	5.23	12.66	12.38	5.05	30.09
Aesculus indica	118.93	56.66	4.91	12.08	16.19	4.74	33.01
Abies pindrow	166.94	56.66	33.34	16.96	16.19	32.20	65.35
Juglans regia	116.93	43.33	10.63	11.88	12.38	10.26	34.52
Morus nigra	124.24	46.66	5.12	12.62	13.33	4.94	30.89
Robinia pseudoacacia	121.93	40.00	4.13	12.38	11.43	3.99	27.80
Pinus walliachiana	210.91	63.33	40.21	21.42	18.10	38.82	78.34
Total	**984.50**	**349.97**	**103.57**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**140.64**	**49.99**	**14.79**	**14.28**	**14.28**	**14.28**	**42.85**
S.E±	**13.39**	**3.42**	**5.78**	**1.36**	**0.95**	**5.58**	**7.65**

Table 11: Floristic composition and phytosociological attributes of Shrub species at Budgam Forest Division (1750 to 2000 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	296.31	56.66	1.21	17.36	14.91	9.24	41.51
Crataegus songarica	221.92	46.66	3.96	13.00	12.28	30.25	55.53
Parrotia jacquemontiana	310.94	70.00	2.21	18.22	18.42	16.88	53.52
Vibernum grandiflorum	328.24	73.33	2.63	19.23	19.30	20.09	58.62
Indigofera heterantha	298.92	86.66	1.12	17.51	22.81	8.56	48.88
Sambucus wightiana	250.64	46.66	1.96	14.68	12.28	14.98	41.94
Total	**1706.97**	**379.97**	**13.09**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**284.49**	**63.32**	**2.18**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**15.13**	**6.06**	**0.39**	**0.88**	**1.59**	**3.02**	**2.70**

Table 12: Floristic composition and phytosociological attributes of Herb species at Budgam Forest Division (1750 to 2000 m)

Herbs	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Artimesia absinthium	6.29	70.00	1.96	9.00	8.60	7.73	25.33
Cynodon dactylon	5.16	66.66	1.62	7.39	8.19	6.39	21.97
Cannabis sativa	3.21	56.66	1.72	4.60	6.97	6.78	18.35
Dactylis glomerata	4.36	73.33	1.22	6.24	9.02	4.81	20.07
Fragaria vesca	8.23	83.33	3.26	11.79	10.25	12.85	34.89
Fritillaria imperialis	3.33	36.66	1.99	4.77	4.51	7.85	17.13
Mentha spicata	6.21	63.33	2.30	8.90	7.79	9.07	25.76
Malva neglecta	6.20	50.00	2.10	8.88	6.15	8.28	23.31
Rumex nepalensis	5.21	53.33	1.98	7.47	6.57	7.81	21.85
Trifolium repens	6.42	76.66	2.10	9.19	9.43	8.28	26.90
Taraxacum officinale	6.60	66.66	1.73	9.45	8.19	6.82	24.46
Urtica dioica	4.40	66.66	2.28	6.30	8.19	8.99	23.48
Viola odorata	4.21	50.00	1.10	6.02	6.14	4.34	16.50
Total	**69.83**	**813.28**	**25.36**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.37**	**62.56**	**1.95**	**7.69**	**7.69**	**7.69**	**23.07**
S.E±	**0.40**	**3.54**	**0.14**	**0.57**	**0.43**	**0.58**	**1.34**

Tangmarg Forest Division (2000 to 2300 m)

The data presented in the tables 13, 14 and 15 pertaining to the Tangmarg Forest Division reveals the presence of seven tree species, six shrub species, and 14 herb species alongside, Hawthorn, *Crataegus songarica*.

Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 85.91, followed by *Juglans regia* (47.21), *Robinia pseudoacacia* (34.99), *Celtris australis* (33.83), *Morus nigra* (33.51), *Aesculus indica* (33.44). The lowest IVI was observed for *Ulmus villosa* (31.11) (Table 13).

Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 74.72, followed by *Vibernum grandiflorum* (53.00), *Parrotia jacquemontiana* (48.00), *Indigofera heterantha* (43.04) and *Rosa weibaana* (41.31). The lowest IVI was observed for *Berberis lyceum* (39.93) (Table 14).

Among the Herb species, the maximum IVI was observed for *Fragaria vesca* (27.68), followed by *Mentha spicata* (25.67), *Trifolium repens* (25.47) and *Cynodon dactylon* (25.06). The lowest IVI was observed for *Fritillaria imperialis* (16.73) (Table 15).

Shopain Forest Division (2000 to 2260 m)

The data presented in the tables 16, 17 and 18 pertaining to the Shopain Forest Division reveals the presence of five tree species, five shrub species, and 13 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 92.47, followed by *Pinus walliachiana* (91.22) and *Robinia pseudoacacia* (45.80) The lowest IVI was observed for *Juglans regia* (33.52) (Table 16).

Among the shrub species in the area, *Parrotia jacquemontiana* was the dominant species with an IVI value of 76.66, followed by *Vibernum grandiflorum* (64.69), *Indigofera heterantha* (61.55) and *Berberis lyceum* (50.73).The lowest IVI was observed for *Crataegus songarica* (46.47) (Table 17).

Among the Herb species, the maximum IVI was observed for *Cynodon dactylon* (34.46), followed by *Fragaria vesca* (31.70), *Urtica dioica* (27.09) and *Malva neglecta* (26.82). The lowest IVI was observed for *Podophyllum hexandrum* (10.71) (Table 18).

Anantnag Forest Division (1800 to 2230 m)

The data presented in the tables 19, 20 and 21 pertaining to the Anantnag Forest Division reveals the presence of six tree species, five shrub species, and 15 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Abies pindrow* with a value of 87.86, followed by *Pinus walliachiana* (78.47), *Aesculus indica* (40.52), *Juglans regia* (36.65) and *Robinia pseudoacacia* (32.23) The lowest IVI was observed for *Ailanthus altissima* (24.27) (Table 19).

Among the shrub species in the area, *Berberis lyceum* was the dominant species with an IVI value of 72.08, followed by *Vibernum grandiflorum* (70.21), *Indigofera heterantha* (56.19) and *Parrotia jacquemontiana* (53.54). The lowest IVI was observed for *Crataegus songarica* (47.98) (Table 20).

Among the Herb species, the maximum IVI was observed for *Fragaria vesca* (29.50), followed by *Taraxacum officinale* (24.69), *Malva neglecta* (24.00) and *Trifolium repens* (23.47). The lowest IVI was observed for *Podophyllum hexandrum* (10.34) (Table 21).

Table 13: Floristic composition and phytosociological attributes of Tree species at Tangmarg Forest Division (2000 to 2300 m)

Trees	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Aesculus indica	102.93	43.33	3.21	13.04	13.83	6.57	33.44
Cedrus deodara	188.21	66.66	19.94	23.84	21.28	40.79	85.91
Celtris australis	98.92	33.33	5.21	12.53	10.64	10.66	33.83
Juglans regia	92.49	36.66	11.63	11.72	11.70	23.79	47.21
Morus nigra	111.31	43.33	2.73	14.10	13.83	5.58	33.51
Robinia pseudoacacia	114.62	50.00	2.21	14.52	15.95	4.52	34.99
Ulmus villosa	80.94	40.00	3.96	10.25	12.77	8.09	31.11
Total	**789.42**	**313.31**	**48.89**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**112.77**	**44.75**	**6.98**	**14.28**	**14.28**	**14.28**	**42.85**
S.E±	**13.38**	**4.16**	**2.47**	**1.68**	**1.33**	**5.05**	**7.44**

Table 14: Floristic composition and phytosociological attributes of Shrub species at Tangmarg Forest Division (2000 to 2300 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	298.94	53.33	0.98	17.28	15.24	7.41	39.93
Crataegus songarica	312.96	66.66	4.97	18.10	19.05	37.57	74.72
Parrotia jacquemontiana	288.31	53.33	2.13	16.67	15.24	16.09	48.00
Rosa webbiana	210.21	43.33	2.22	12.15	12.38	16.78	41.31
Vibernum grandiflorum	316.31	73.33	1.82	18.29	20.95	13.76	53.00
Indigofera heterantha	302.93	60.00	1.11	17.51	17.14	8.39	43.04
Total	**1729.66**	**349.98**	**13.23**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**288.27**	**58.33**	**2.20**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**14.94**	**4.04**	**0.54**	**0.86**	**1.15**	**4.14**	**4.92**

Table 15: Floristic composition and phytosociological attributes of Herb species at Tangmarg Forest Division (2000 to 2300 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Cynodon dactylon	7.24	80.00	1.78	9.12	9.76	6.18	25.06
Conyza canadensis	4.23	33.33	2.16	5.33	4.06	7.50	16.89
Dactylis glomerata	5.31	76.66	1.36	6.69	9.35	4.72	20.76
Fragaria vesca	7.12	70.00	2.93	8.97	8.54	10.17	27.68
Fritillaria imperialis	3.89	36.66	2.12	4.90	4.47	7.36	16.73
Hypericum perforatum	4.61	50.00	1.73	5.81	6.09	6.00	17.90
Mentha spicata	7.18	70.00	2.33	9.04	8.54	8.09	25.67
Malva neglecta	6.66	53.33	1.98	8.39	6.50	6.87	21.76
Podophyllum hexandrum	4.23	36.66	2.48	5.33	4.47	8.61	18.41
Rumex nepalensis	4.81	40.00	1.70	6.05	4.88	5.90	16.83
Trifolium repens	6.68	76.66	2.22	8.41	9.35	7.71	25.47
Taraxacum officinale	5.98	70.00	1.59	7.53	8.54	5.52	21.59
Urtica dioica	5.92	60.00	2.86	7.46	7.32	9.93	24.71
Viola odorata	5.53	66.66	1.57	6.97	8.13	5.44	20.54
Total	**79.39**	**819.96**	**28.81**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.67**	**58.56**	**2.05**	**7.14**	**7.14**	**7.14**	**21.42857**
S.E±	**0.31**	**4.45**	**0.12**	**0.39**	**0.54**	**0.44**	**1.29**

Table 16: Floristic composition and phytosociological attributes of Tree species at Shopain Forest Division (2000 to 2260 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Cedrus deodara	210.94	63.33	21.24	26.93	24.71	40.83	92.47
Juglans regia	66.92	33.33	6.23	8.54	13.00	11.98	33.52
Morus nigra	131.21	36.33	3.16	16.75	14.17	6.07	36.99
Robinia pseudoacacia	150.94	53.33	2.97	19.28	20.81	5.71	45.80
Pinus walliachiana	223.21	70.00	18.42	28.5	27.31	35.41	91.22
Total	**783.22**	**256.32**	**52.02**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**156.64**	**51.26**	**10.40**	**20.00**	**20.00**	**20.00**	**60.00**
S.E±	**23.38**	**7.23**	**3.91**	**3.62**	**2.82**	**7.52**	**13.15**

Table 17: Floristic composition and phytosociological attributes of Shrub species at Shopain Forest Division (2000 to 2260 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	336.64	40.00	1.93	22.50	12.5	15.73	50.73
Crataegus songarica	112.93	36.66	3.37	7.54	11.46	27.47	46.47
Parrotia jacquemontiana	397.24	83.33	2.94	26.56	26.04	23.96	76.56
Vibernum grandiflorum	350.96	76.66	2.12	23.46	23.96	17.27	64.69
Indigofera heterantha	298.24	83.33	1.91	19.94	26.04	15.57	61.55
Total	**1496.01**	**319.98**	**12.27**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**299.202**	**63.996**	**2.454**	**20.00**	**20.00**	**20.00**	**60.00**
S.E±	**49.18**	**10.56**	**0.29**	**3.29**	**3.30**	**2.41**	**5.32**

Table 18: Floristic composition and phytosociological attributes of Herb species at Shopain Forest Division (2000 to 2260 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Cynodon dactylon	8.32	86.66	3.24	11.70	11.02	11.74	34.46
Dactylis glomerata	4.12	66.66	1.31	5.79	8.47	4.75	19.01
Fragaria vesca	7.63	80.00	2.98	10.73	10.17	10.80	31.70
Fritillaria imperialis	5.52	50.00	3.16	7.76	6.36	11.45	25.57
Hypericum perforatum	4.98	53.33	1.89	7.00	6.78	6.85	20.63
Mentha spicata	5.28	60.00	2.13	7.43	7.63	7.72	22.78
Malva neglecta	7.36	66.66	2.21	10.35	8.47	8.00	26.82
Podophyllum hexandrum	2.11	26.66	1.20	2.97	3.39	4.35	10.71
Rumex nepalensis	4.86	46.66	1.79	6.83	5.93	6.49	19.25
Trifolium repens	5.28	60.00	1.96	7.43	7.63	7.10	22.16
Taraxacum officinale	5.57	66.66	1.55	7.83	8.47	5.61	21.91
Urtica dioica	5.98	70.00	2.70	8.41	8.90	9.78	27.09
Viola odorata	4.10	53.33	1.48	5.77	6.78	5.36	17.91
Total	**71.11**	**786.62**	**27.60**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.47**	**60.50923077**	**2.12**	**7.69**	**7.69**	**7.69**	**23.07**
S.E±	**0.46**	**4.39**	**0.19**	**0.64**	**0.55**	**0.70**	**1.73**

Table 19: Floristic composition and phytosociological attributes of Tree species at Anantnag Forest Division (1800 to 2230 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Ailanthus altissima	98.91	33.33	2.31	9.76	10.99	3.52	24.27
Aesculus indica	170.24	56.66	3.32	16.79	18.68	5.05	40.52
Abies pindrow	276.31	70.00	24.64	27.26	23.08	37.52	87.86
Juglans regia	130.91	43.33	6.21	12.91	14.29	9.45	36.65
Robinia pseudoacacia	126.42	46.66	2.88	12.47	15.38	4.38	32.23
Pinus walliachiana	210.93	53.33	26.32	20.81	17.58	40.08	78.47
Total	**1013.72**	**303.31**	**65.68**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**168.95**	**50.55**	**10.94**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**24.75**	**4.74**	**4.28**	**2.44**	**1.56**	**6.53**	**9.98**

Table 20: Floristic composition and phytosociological attributes of Shrub species at Anantnag Forest Division (1800 to 2230 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lyceum	298.12	66.66	2.92	25.55	22.73	23.80	72.08
Crataegus songarica	117.31	40.00	2.98	10.06	13.63	24.29	47.98
Parrotia jacquemontiana	210.94	53.33	2.12	18.08	18.18	17.28	53.54
Vibernum grandiflorum	316.32	70.00	2.36	27.12	23.86	19.23	70.21
Indigofera heterantha	223.91	63.33	1.89	19.19	21.60	15.40	56.19
Total	**1166.60**	**293.32**	**12.27**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**233.32**	**58.66**	**2.45**	**20.00**	**20.00**	**20.00**	**60.00**
S.E±	**35.45**	**5.43**	**0.21**	**3.03**	**1.85**	**1.76**	**4.74**

Table 21: Floristic composition and phytosociological attributes of Herb species at Anantnag Forest Division (1800 to 2230 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Artimesia absinthium	4.32	56.66	1.46	5.26	6.64	4.62	16.52
Cynodon dactylon	5.53	50.00	1.96	6.73	5.86	6.20	18.79
Cannabis sativa	5.63	56.66	2.12	6.85	6.64	6.71	20.20
Dactylis glomerata	4.66	46.66	1.89	5.67	5.47	5.98	17.12
Fragaria vesca	8.12	83.33	3.11	9.88	9.77	9.85	29.50
Fritillaria imperialis	4.43	43.33	3.10	5.39	5.08	9.81	20.28
Hypericum perforatum	5.23	40.00	1.98	6.36	4.69	6.27	17.32
Mentha spicata	6.60	63.33	2.46	8.03	7.42	7.79	23.24
Malva neglecta	7.50	66.66	2.23	9.13	7.81	7.06	24.00
Podophyllum hexandrum	2.16	33.33	1.21	2.63	3.91	3.80	10.34
Rumex nepalensis	4.74	46.66	1.93	5.77	5.47	6.12	17.36
Trifolium repens	6.41	70.00	2.36	7.80	8.20	7.47	23.47
Taraxacum officinale	7.69	73.33	2.13	9.36	8.59	6.74	24.69
Urtica dioica	4.90	66.66	2.13	5.96	7.81	6.74	20.51
Viola odorata	4.26	56.66	1.53	5.18	6.64	4.84	16.66
Total	**82.18**	**853.27**	**31.59**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.47**	**56.88**	**2.10**	**6.66**	**6.66**	**6.66**	**20.00**
S.E±	**0.40**	**3.55**	**0.13**	**0.49**	**0.41**	**0.43**	**1.17**

Langate Forest Division (1700 to 2060 m)

The data presented in the tables 22, 23 and 24 pertaining to the Langate Forest Division reveals the presence of six tree species, three shrub species, and 12 herb species alongside, Hawthorn, *Crataegus songarica*.

Among the tree species, the highest Importance Value Index (IVI) was observed for *Pinus walliachiana* with a value of 87.06, followed by *Cedrus deodara* (82.70), *Aesculus indica* (38.31), *Juglans regia* (32.60) and *Robinia pseudoacacia* (31.32). The lowest IVI was observed for *Ulmus villosa* (28.01) (Table 22).

Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 85.07, followed by *Vibernum grandiflorum* (79.50) and *Parrotia jacquemontiana* (67.81). The lowest IVI was observed for *Indigofera heterantha* (67.62) (Table 23).

Among the Herb species, the maximum IVI was observed for *Fragaria vesca* (37.55), followed by *Taraxacum officinale* (30.44), *Artimesia absinthium* (29.84) and *Dactylis glomerata* (28.35). The lowest IVI was observed for *Podophyllum hexandrum* (13.12) (Table 24).

Kamraj Forest Division (2100 to 2350 m)

The data presented in the tables 25, 26 and 27 pertaining to the Kamraj Forest Division reveals the presence of six tree species, six shrub species, and 13 herb species alongside, Hawthorn, *Crataegus songarica*.

Among the tree species, the highest Importance Value Index (IVI) was observed for *Pinus walliachiana* with a value of 75.48, followed by *Cedrus deodara* (69.96), *Abies pindrow* (61.62), *Robinia pseudoacacia* (33.15) and *Ailanthus altissima* (30.93). The lowest IVI was observed for *Morus nigra* (28.86) (Table 25).

Among the shrub species in the area, *Vibernum grandiflorum* was the dominant species with an IVI value of 57.86, followed by *Indigofera heterantha* (53.96), *Berberis lycium* (53.02), *Crataegus songarica* (46.28) and *Rosa weibaana* (44.73). The lowest IVI was observed for *Parrotia jacquemontiana* (44.15) (Table 26).

Among the Herb species, the maximum IVI was observed for *Cynodon dactylon* (28.45), followed by *Trifolium repens* (26.97), *Fragaria vesca* (26.68) and *Conyza canadensis* (25.62). The lowest IVI was observed for *Fritillaria imperialis* (16.85) (Table 27).

Kehmil Forest Division (2000 to 2060 m)

The data presented in the tables 28, 29, 30 pertaining to the Kehmil Forest Division reveals the presence of seven tree species, four shrub species, and 12 herb species alongside, Hawthorn, *Crataegus songarica*.

Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 65.07, followed by *Pinus walliachiana* (61.11), *Abies pindrow* (56.00), *Ailanthus altissima* (35.22), *Aesculus indica* (31.28) and *Juglanas regia*. The lowest IVI was observed for *Morus alba* (21.02) (Table 28).

Among the shrub species in the area, *Vibernum grandiflorum* was the dominant species with an IVI value of 79.53, followed by *Parrotia jacquemontiana* (76.53) and *Crataegus songarica* (72.41). The lowest IVI was observed for *Indigofera heterantha* (71.53) (Table 29).

Among the Herb species, the maximum IVI was observed for *Malva neglecta* (28.85), followed by *Cynodon dactylon* (28.63), *Trifolium repens* (28.17) and *Cannabis sativa* (27.21). The lowest IVI was observed for *Viola odorata* (19.31) (Table 30).

Table 22: Floristic composition and phytosociological attributes of Tree species at Langate Forest Division (1700 to 2060 m)

Trees	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Aesculus indica	150.93	43.44	2.91	16.45	16.92	4.94	38.31
Cedrus deodara	219.32	56.66	21.64	23.90	22.07	36.73	82.70
Juglans regia	98.94	33.33	5.21	10.78	12.98	8.84	32.60
Robinia pseudoacacia	110.93	36.66	2.93	12.09	14.28	4.95	31.32
Pinus walliachiana	221.31	60.00	23.32	24.11	23.37	39.58	87.06
Ulmus villosa	116.21	26.66	2.92	12.67	10.38	4.96	28.01
Total	**917.64**	**256.75**	**58.92**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**152.94**	**42.79**	**9.82**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**20.78**	**5.00**	**3.72**	**2.26**	**1.94**	**6.32**	**10.30**

Table 23: Floristic composition and phytosociological attributes of Shrub species at Langate Forest Division (1700 to 2060 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Crataegus songarica	321.96	73.33	3.96	28.39	24.44	32.24	85.07
Parrotia jacquemontiana	210.42	76.66	2.91	18.56	25.55	23.70	67.81
Vibernum grandiflorum	302.63	80.00	3.21	26.69	26.67	26.14	79.50
Indigofera heterantha	298.93	70.00	2.20	26.36	23.34	17.92	67.62
Total	**1133.94**	**299.99**	**12.28**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**283.48**	**74.99**	**3.07**	**25.00**	**25.00**	**25.00**	**75.00**
S.E±	**24.87**	**2.15**	**0.36**	**2.19**	**0.71**	**2.96**	**4.35**

Table 24: Floristic composition and phytosociological attributes of Herb species at Langate Forest Division (1700 to 2060 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Artimesia absinthium	7.12	76.66	2.13	10.95	10.36	8.53	29.84
Cynodon dactylon	5.64	66.66	1.69	8.68	9.01	6.77	24.46
Cannabis sativa	4.42	63.33	2.20	6.80	8.56	8.81	24.17
Dactylis glomerata	6.23	76.66	2.10	9.58	10.36	8.41	28.35
Fragaria vesca	8.63	86.66	3.14	13.27	11.71	12.57	37.55
Fritillaria imperialis	2.23	33.33	1.94	3.43	4.50	7.77	15.70
Podophyllum hexandrum	2.40	33.33	1.23	3.70	4.50	4.92	13.12
Rumex nepalensis	5.20	53.33	2.11	7.99	7.21	8.44	23.64
Trifolium repens	5.90	66.66	2.21	9.07	9.01	8.85	26.93
Taraxacum officinale	7.81	73.33	2.13	12.00	9.91	8.53	30.44
Urtica dioica	4.55	60.00	2.29	6.99	8.11	9.16	24.26
Viola odorata	4.90	50.00	1.81	7.54	6.76	7.24	21.54
Total	**65.03**	**739.95**	**24.98**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.41**	**61.66**	**2.08**	**8.33**	**8.33**	**8.33**	**25.00**
S.E±	**0.55**	**4.82**	**0.12**	**0.85**	**0.65**	**0.51**	**1.88**

Table 25: Floristic composition and phytosociological attributes of Tree species at Kamraj Forest Division (2100 to 2350 m)

Trees	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Ailanthus altissima	160.92	46.66	2.31	13.06	14.58	3.29	30.93
Abies pindrow	210.31	50.00	20.32	17.07	15.62	28.93	61.62
Cedrus deodara	280.93	63.33	19.21	22.81	19.80	27.35	69.96
Morus nigra	130.42	43.33	3.32	10.59	13.54	4.73	28.86
Robinia pseudoacacia	160.91	50.00	3.13	13.06	15.63	4.46	33.15
Pinus walliachiana	288.32	66.66	21.94	23.41	20.83	31.24	75.48
Total	**1231.81**	**319.98**	**70.23**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**205.30**	**53.33**	**11.70**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**25.17**	**3.56**	**3.65**	**2.04**	**1.11**	**5.20**	**8.06**

Table 26: Floristic composition and phytosociological attributes of Shrub species at Kamraj Forest Division (2100 to 2350 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lycium	330.41	56.66	2.96	18.73	15.6	18.69	53.02
Crataegus songarica	216.92	40.00	3.64	12.30	11.00	22.98	46.28
Parrotia jacquemontiana	230.31	60.00	2.31	13.06	16.51	14.58	44.15
Vibernum grandiflorum	340.91	76.66	2.76	19.33	21.10	17.43	57.86
Indigofera heterantha	346.31	73.33	2.24	19.63	20.19	14.14	53.96
Rosa weibaana	298.93	56.66	1.93	16.95	15.60	12.18	44.73
Total	**1763.79**	**363.31**	**15.84**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**293.96**	**60.55**	**2.64**	**16.66**	**16.66**	**16.66**	**50.00**
S.E±	**21.57**	**5.00**	**0.23**	**1.22**	**1.37**	**1.46**	**2.14**

Table 27: Floristic composition and phytosociological attributes of Herb species at Kamraj Forest Division (2100 to 2350 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Cynodon dactylon	7.73	73.33	2.21	10.73	9.95	7.77	28.45
Cannabis sativa	4.63	50.00	2.31	6.43	6.79	8.12	21.34
Conyza canadensis	5.66	50.00	3.12	7.86	6.79	10.97	25.62
Dactylis glomerata	4.36	53.33	1.83	6.05	7.24	6.44	19.73
Fragaria vesca	6.60	66.66	2.41	9.16	9.05	8.47	26.68
Fritillaria imperialis	3.33	33.33	2.19	4.63	4.52	7.70	16.85
Hypericum perforatum	5.61	56.66	2.12	7.79	7.69	7.46	22.94
Mentha spicata	5.98	60.00	1.86	8.30	8.15	6.54	22.99
Malva neglecta	6.28	60.00	1.73	8.72	8.15	6.08	22.95
Trifolium repens	6.66	73.33	2.21	9.25	9.95	7.77	26.97
Taraxacum officinale	5.40	50.00	2.35	7.50	6.79	8.26	22.55
Urtica dioica	4.47	56.66	2.23	6.21	7.69	7.84	21.74
Viola odorata	5.31	53.33	1.87	7.37	7.24	6.58	21.19
Total	**72.02**	**736.63**	**28.44**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.54**	**56.66**	**2.18**	**7.69**	**7.69**	**7.69**	**23.07**
S.E±	**0.32**	**2.97**	**0.09**	**0.44**	**0.40**	**0.34**	**0.88**

Table 28: Floristic composition and phytosociological attributes of Tree species at Kehmil Forest Division (2000 to 2060 m)

Species	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Ailanthus altissima	210.94	56.66	3.31	15.44	16.35	3.73	35.52
Aesculus indica	198.63	40.00	4.62	14.54	11.53	5.21	31.28
Cedrus deodara	216.42	66.66	26.63	15.84	19.23	30.00	65.07
Juglanas regia	196.93	33.33	5.31	14.41	9.61	5.98	30.00
Morus alba	130.94	26.66	3.32	9.58	7.70	3.74	21.02
Abies pindrow	201.64	60.00	21.24	14.75	17.31	23.94	56.00
Pinus walliachiana	210.93	63.33	24.32	15.44	18.27	27.40	61.11
Total	**1366.43**	**346.64**	**88.75**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**195.20**	**49.52**	**12.67**	**14.28**	**14.28**	**14.28**	**42.85**
S.E±	**11.76**	**6.09**	**3.92**	**0.86**	**1.75**	**4.42**	**6.34**

Table 29: Floristic composition and phytosociological attributes of Shrub species at Kehmil Forest Division (2000 to 2060 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Crataegus songarica	150.91	53.33	3.61	18.51	21.92	31.98	72.41
Parrotia jacquemontiana	210.60	60.00	2.94	25.83	24.66	26.04	76.53
Vibernum grandiflorum	233.32	63.33	2.81	28.62	26.02	24.89	79.53
Indigofera heterantha	220.41	66.66	1.93	27.04	27.40	17.09	71.53
Total	**815.24**	**243.32**	**11.29**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**203.81**	**60.83**	**2.82**	25.00	**25.00**	**25.00**	75.00
S.E±	**21.28**	**2.54**	**0.21**	**2.61**	**1.04**	**1.90**	**1.78**

Table 30: Floristic composition and phytosociological attributes of Herb species at Kehmil Forest Division (2000 to 2060 m)

Shrubs	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Cynodon dactylon	7.74	70.00	1.98	11.44	9.81	7.38	28.63
Cannabis sativa	5.45	66.66	2.66	8.05	9.35	9.91	27.31
Conyza canadensis	4.62	43.33	2.34	6.83	6.08	8.72	21.63
Dactylis glomerata	5.36	66.66	2.18	7.92	9.35	8.12	25.39
Fritillaria imperialis	4.26	43.33	2.78	6.30	6.08	10.36	22.74
Hypericum perforatum	5.62	60.00	2.21	8.31	8.41	8.23	24.95
Malva neglecta	7.12	73.33	2.16	10.52	10.28	8.05	28.85
Rumex nepalensis	5.21	56.66	2.13	7.70	7.94	7.94	23.58
Trifolium repens	6.40	70.00	2.39	9.46	9.81	8.90	28.17
Taraxacum officinale	6.23	60.00	1.96	9.21	8.41	7.30	24.92
Urtica dioica	4.89	53.33	2.68	7.23	7.48	9.99	24.70
Viola odorata	4.76	50.00	1.37	7.03	7.00	5.10	19.13
Total	**67.66**	**713.30**	**26.84**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.63**	**59.44**	**2.23**	**8.33**	**8.33**	**8.33**	**25.53**
S.E±	**0.30**	**2.99**	**0.08**	**0.45**	**0.41**	**0.30**	**0.70**

Baramulla Forest Division (1900 to 2150 m)

The data presented in the tables 31, 32 and 33 pertaining to the Baramulla Forest Division reveals the presence of eight tree species, five shrub species and 12 herb species alongside, Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 72.37, followed by *Pinus walliachiana* (69.08), *Juglanas regia* (33.29), *Aesculus indica* (31.06), *Robinia pseudocacia* (26.80), *Celtris australis* (24.23) and *Morus nigra* (22.52).The lowest IVI was observed for *Morus alba* (20.64) (Table 31).

Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 67.58, followed by *Berberis lycium* (61.67), *Parrotia jacquemontiana* (61.00) and *Vibernum grandiflorum* (55.08). The lowest IVI was observed for *Indigofera heterantha* (54.67) (Table 32).

Among the Herb species, the maximum IVI was observed for *Cynodon dactylon* (33.68), followed by *Taraxacum officinale* (29.41), *Mentha spicata* (27.00) and *Fritillaria imperialis* (26.05). The lowest IVI was observed for *Viola odorata* (19.93) (Table 33).

The IVI of *Crataegus songarica* was found highest (85.07) for Langate Forest Division. This was followed by Tangmarg Forest Division (72.74), Kehmil Forest Division (72.41), Bandipora Forest Division (69.69), Baramulla Forest Division (67.58), Sindh Forest Division (61.79), Budgam Forest Division (55.53), Anantnag Forest Division (47.48), Shopain Forest Division (46.47). The lowest IVI was recorded for Kamraj Forest Division (46.28) (Fig 3).

Shannon Wiener diversity index

In case of trees, Shannon Wiener diversity index was recorded highest (3.21) for Anantnag Forest Division and lowest (1.69) for Shopain Forest Division. In case of Shrubs, Sindh Forest division recorded maximum (1.73)

Shannon Wiener diversity index and minimum in case of Langate Forest Division (1.03). For Herbs, Kamraj Forest Division recorded maximum Shannon Wiener diversity index (3.97) while as minimum was recorded for Bandipora Forest Division (2.46) (Table 34).

Table 31: Floristic composition and phytosociological attributes of Tree species at Baramulla Forest Division (1900 to 2150 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Aesculus indica	197.94	40.00	2.98	14.76	11.32	4.98	31.06
Cedrus deodara	280.93	70.00	18.92	20.94	19.81	31.62	72.37
Celtris australis	110.43	36.66	3.36	8.23	10.38	5.62	24.23
Juglanas regia	177.92	40.00	5.21	13.26	11.32	8.71	33.29
Morus nigra	116.34	33.33	2.64	8.67	9.44	4.41	22.52
Morus alba	110.93	30.00	2.32	8.27	8.49	3.88	20.64
Robinia pseudocacia	130.49	40.00	3.44	9.73	11.32	5.75	26.80
Pinus walliachiana	216.32	63.33	20.96	16.13	17.92	35.03	69.08
Total	**1341.30**	**353.32**	**59.83**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**167.66**	**44.16**	**7.47**	**12.49**	**12.5**	**12.50**	**37.50**
S.E±	**21.84**	**5.1**	**2.74**	**1.62**	**1.44**	**4.58**	**7.40**

Table 32: Floristic composition and phytosociological attributes of Shrub species at Baramulla Forest Division (1900 to 2150 m)

Shrubs	Avg. Density/ha	Frequency (%)	Avg. Basal area/ha (m^2)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Berberis lycium	210.32	50.00	2.91	22.22	17.65	21.8	61.67
Crataegus songarica	166.62	43.33	4.63	17.61	15.29	34.68	67.58
Parrotia jacquemontiana	197.91	66.66	2.21	20.92	23.53	16.55	61.00
Vibernum grandiflorum	180.42	60.00	1.98	19.07	21.18	14.83	55.08
Indigofera heterantha	190.93	63.33	1.62	20.18	22.35	12.14	54.67
Total	**946.20**	**283.32**	**13.35**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**189.24**	**56.66**	**2.67**	**20.00**	**20.00**	**20.00**	**60.00**
S.E±	**7.45**	**4.34**	**0.53**	**0.78**	**1.53**	**3.99**	**2.38**

Table 33: Floristic composition and phytosociological attributes of Herb species at Baramulla Forest Division (1900 to 2150 m)

Species	Avg. Density/m²	Frequency (%)	Avg. Basal area(cm²/m²)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI
Artimesia absinthium	6.23	66.66	1.93	9.13	9.43	7.33	25.89
Cynodon dactylon	7.76	73.33	3.12	11.37	10.38	11.85	33.66
Dactylis glomerata	4.31	43.33	2.43	6.32	6.13	9.23	21.68
Fragaria vesca	4.96	50.00	2.12	7.27	7.08	8.05	22.40
Fritillaria imperialis	5.41	56.66	2.66	7.93	8.02	10.10	26.05
Hypericum perforatum	5.21	56.66	2.13	7.63	8.02	8.09	23.74
Mentha spicata	6.24	73.33	1.97	9.14	10.38	7.48	27.00
Malva neglecta	5.97	73.33	1.61	8.75	10.38	6.12	25.25
Rumex nepalensis	4.86	43.33	1.93	7.12	6.13	7.33	20.58
Taraxacum officinale	7.21	73.33	2.23	10.56	10.38	8.47	29.41
Urtica dioica	5.11	50.00	2.61	7.49	7.07	9.91	24.47
Viola odorata	4.98	46.66	1.59	7.29	6.66	6.04	19.93
Total	**68.25**	**706.62**	**26.33**	**100.00**	**100.00**	**100.00**	**300.00**
Mean	**5.68**	**58.88**	**2.19**	**8.33**	**8.33**	**8.33**	**25.00**
S.E±	**0.30**	**3.57**	**1.22**	**0.44**	**0.50**	**0.46**	**1.06**

Table 34: Shannon Wiener diversity index of trees, shrubs and herbs in different Forest Divisions

Forest Division	Trees	Shrubs	Herbs
Sindh Forest Division	2.13	1.73	2.97
Bandipora Forest Division	1.83	1.34	2.46
Budgam Forest Division	2.28	1.27	2.77
Tangmarg Forest Division	1.76	1.36	3.12
Shopain Forest Division	1.69	1.12	2.98
Anantnag Forest Division	3.21	1.06	3.86
Langate Forest Division	2.23	1.03	3.12
Kamraj Forest Division	2.96	1.29	3.97
Kehmil Forest Division	3.06	1.12	3.64
Baramulla Forest Division	2.87	1.49	3.14

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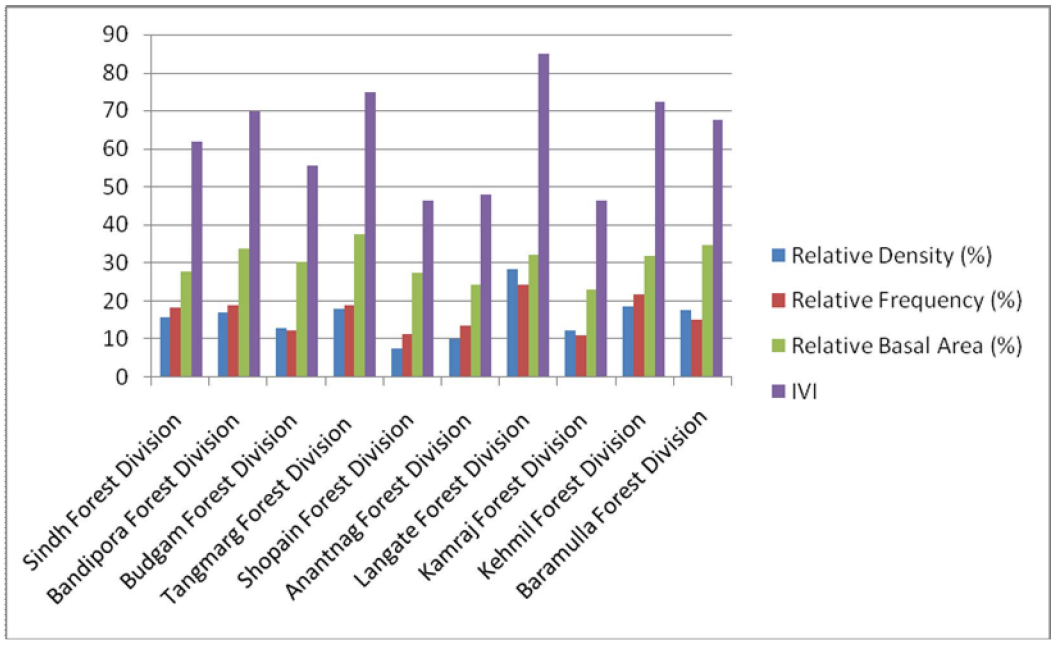


Fig 3: IVI of *Crataegus songarica* in different Forest Divisions

4.2 To study propagation of *Crataegus songarica* through seeds and cuttings

Studies were conducted to propagate *Crataegus songarica* both through seeds and cuttings

4.2.1 Morphometric seed characteristics of *Crataegus songarica* through seeds

Table 35 shows the morphometric seed characteristics of Hawthorn, *Crataegus songarica* in the Kashmir Himalayas. The studies conducted provided valuable insights into various morphometric parameters for the seeds of Hawthorn. Hawthorn exhibited a maximum seed weight of 13.48 g per 100 seeds, a minimum weight of 9.67 g, and an average weight of 11.49 g per 100 seeds. In terms of seed diameter, Hawthorn displayed a range from 4.39 mm to 6.64 mm, with an average diameter of 5.65 mm. The seed length varied between 7.26 mm and 8.21 mm, with an average length of 7.67 mm. Hawthorn's seed moisture content ranged from 7.96% to 9.31%, with an average moisture content of 8.46%. These findings provide valuable information about the morphological characteristics of Hawthorn seeds in the Kashmir Himalayas.

4.2.2 Propagation of *Crataegus songarica* through seeds

Germination percentage

The studies conducted reported a significant effect of scarification and stratification treatments on the germination percentage of Hawthorn, *Crataegus songarica*. Among the treatment groups, the highest germination percentage of 36.66% was observed in T5, which involved scarification with concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. T5 remained statistically at par with T4, where scarification with concentrated sulfuric acid (50%) was combined with a cold stratification period of 60 days, resulting in a germination percentage of 33.33% and T3, employing scarification with concentrated sulfuric acid (50%) and a cold stratification period of 50 days, demonstrated a germination percentage of 31.66%. Meanwhile, T2, utilizing scarification with concentrated sulfuric acid (50%) and a cold stratification period

of 40 days, yielded a germination percentage of 26.66%. The germination percentage for T6, involving mechanical scarification using a hammer, was 25.00%. Lastly, the lowest germination percentage of 10.00% was observed in the control. It was further revealed that T2 remained statistically at par with T1, T3 remained statistically at par with T2 and T4, T4 remained statistically at par with T5 and T2 remained statistically at par with T6. Overall, the data from the table and fig clearly indicate that scarification with sulfuric acid, coupled with cold stratification periods ranging from 40 to 70 days, significantly enhanced the germination percentage of Hawthorn, *Crataegus songarica* (Table 36, Fig 4).

Germination energy (%)

The studies conducted reported a noteworthy influence of scarification and stratification treatments on the germination energy of Hawthorn, *Crataegus songarica*. Among the treatments, the highest germination energy of 31.66% was observed in T5, which involved scarification with concentrated sulfuric acid (50%) followed by cold stratification for 70 days. T5 remained statistically at par with T4, with a germination energy of 30.00%, achieved through scarification with concentrated sulfuric acid (50%) and cold stratification for 60 days, T3 exhibited a germination energy of 28.33% by employing scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days and T2, with a germination energy of 23.33%, where scarification with concentrated sulfuric acid (50%) was combined with cold stratification for 40 days. T6, using mechanical scarification with a hammer, yielded a germination energy of 21.66%. In case of T1, employing scarification with concentrated sulfuric acid (50%), 16.66% of germination energy was observed. The control (T0) had the lowest germination energy of 6.66%. It was further revealed that T2 remained statistically at par with T1, T3 and T4 was found at par with T5. Based on the data presented in the table 36, it is evident that scarification with sulfuric acid, coupled with cold stratification ranging from 40 to 70 days, effectively increased the germination energy in Hawthorn, *Crataegus songarica* (Table 36, Fig 4).

Germination value

The conducted studies reported that the germination value of Hawthorn, *Crataegus songarica* was significantly affected by scarification and stratification treatments. The results indicated varying effects of different treatment combinations on germination value. Among these, the highest germination value of 4.21 was observed in T5, where scarification with concentrated sulfuric acid (50%) was followed by 70 days of cold stratification. T5 remained statistically at par with T4, which exhibited a germination value of 3.87, involving scarification with concentrated sulfuric acid (50%) and 60 days of cold stratification and T3, which showed a germination value of 4.07, employing scarification with concentrated sulfuric acid (50%) and 50 days of cold stratification. T2 resulted in a germination value of 2.06, with scarification using concentrated sulfuric acid (50%) and 40 days of cold stratification. Mechanical scarification with a hammer (T6) yielded a germination value of 1.75, while T1, involving scarification with concentrated sulfuric acid (50%), showed a germination value of 1.23. Notably, the control (T0) exhibited the lowest germination value of 0.62. It was further revealed that T1 remained statistically at par with T2 and T5 remained statistically at par with T4. The table clearly demonstrates that scarification with sulfuric acid and cold stratification for a duration ranging from 40 to 70 days significantly increased the germination value in Hawthorn (*Crataegus songarica*) (Table 36, Fig 4).

Length of root (cm)

The studies conducted reported a significant impact of scarification and stratification treatments on root development in Hawthorn, *Crataegus songarica*. The results demonstrated varying root lengths across different treatment conditions. The highest root length of 5.69 cm was observed in T3, where the seeds underwent scarification using concentrated sulfuric acid (50%) followed by cold stratification for 50 days. This was followed by T5, which exhibited a root

length of 4.77 cm after scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days and T4, which showed a root length of 4.66 cm after scarification with concentrated sulfuric acid (50%) and cold stratification for 60 days. T6, involving mechanical scarification with a hammer, resulted in a root length of 3.53 cm. T2 exhibited a root length of 3.47 cm following scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days. Finally, T1, where scarification was performed solely with concentrated sulfuric acid (50%), showed a root length of 3.20 cm. It was further revealed that T1 remained statistically at par with T2. The control group (T0) recorded the lowest root length of 1.55 cm (Table 37, Fig 5).

Average number of roots

The studies conducted reported a significant impact of scarification and stratification treatments on the average number of roots in Hawthorn, *Crataegus songarica*. The results indicated notable variations among the treatment groups.

Among the treatments, T3, involving scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days, exhibited the highest average number of roots at 9.66. T3 remained statistically at par with T4, with scarification using concentrated sulfuric acid (50%) and cold stratification for 60 days, which recorded an average of 9.00 roots and T5, employing scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days, showed an average of 8.66 roots. T2, comprising scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, had an average of 8.33 roots. T1, involving scarification with concentrated sulfuric acid (50%), yielded an average of 7.69 roots. Lastly, T6, which utilized mechanical scarification with a hammer, resulted in an average of 7.00 roots. The control (T0) exhibited the lowest average number of roots at 4.66. It was further revealed that T3, T4, T5 and T6 remained statistically at par with one another. These findings highlight the influence of

scarification and stratification treatments on root development in Hawthorn, *Crataegus songarica* (Table 37, Fig 5).

Seedling height (cm)

The conducted studies demonstrated that scarification and stratification treatments have a significant impact on the height of Hawthorn seedlings, *Crataegus songarica*. The highest recorded seedling height of 14.37 cm was observed in treatment T5, which involved scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days. This was followed by T4, with a seedling height of 12.17 cm, which included scarification with concentrated sulfuric acid (50%) and cold stratification for 60 days and T3, which resulted in a seedling height of 12.00 cm, achieved through scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days. In treatment T6, where mechanical scarification with a hammer was employed, the seedling height reached 11.47 cm. Treatment T2, involving scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, resulted in a seedling height of 9.41 cm. The lowest seedling height of 8.50 cm was recorded in treatment T1, which employed scarification with concentrated sulfuric acid (50%) alone. It was further revealed that T1 remained statistically at par with T2, T3, T4 and T6 remained statistically at par with one another. The control group (T0) exhibited the lowest seedling height of 5.64 cm (Table 37, Fig 6).

Vigour index

The studies conducted demonstrated that scarification and stratification treatments have a significant impact on the vigor index of Hawthorn , *Crataegus songarica*. The highest vigour index of 526.26 was observed in treatment T5, which involved scarification using concentrated sulfuric acid (50%) followed by cold stratification for 70 days. This was followed by T4, which exhibited a vigor index of 404.10, achieved through scarification using concentrated sulfuric acid (50%) and cold stratification for 60 days and T3, which utilized scarification with

concentrated sulfuric acid (50%) and cold stratification for 50 days, resulted in a vigor index of 379.58. Mechanical scarification using a hammer in treatment T6 yielded a vigor index of 287.78, while treatment T2, involving scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, produced a vigor index of 250.18. The lowest vigor index of 56.40 was recorded in the control (Table 37, Fig 6).

Total Leaf area (cm^2)

The conducted studies have provided valuable insights into the effects of scarification and stratification treatments on the leaf area of Hawthorn, *Crataegus songarica*. The treatment that produced the highest leaf area, measuring 27.71 cm^2, was T5. This treatment involved scarification using concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. This was followed by T4, which yielded a leaf area of 25.37 cm^2 by employing scarification with concentrated sulfuric acid (50%) and a cold stratification period of 60 days and T6, utilizing mechanical scarification with a hammer, exhibited a leaf area of 25.53 cm^2. The control treatment, T0, recorded the lowest leaf area of 23.21 cm^2 (Table 37).

Table 35: Seed characteristics of *Crataegus songarica*

SeedCharacteristic	Maximum	Minimum	Average
Seed weight (g/100 seeds)	13.48	9.67	11.49
Seed diameter (mm)	6.64	4.39	5.65
Seed length (mm)	8.21	7.26	7.67
Seed Moisture (%)	9.31	7.96	8.46

Table 36: Effect of seed scarification and stratification on Germination behavior of Hawthorn, *Crataegus songarica*

Parameters Treatments	Germination (%)	Germination energy (%)	Germination value
T0 (Control)	10.00	6.66	0.62
T1	20.00	16.66	1.23
T2	26.66	23.33	2.06
T3	31.66	28.33	4.07
T4	33.33	30.00	3.87
T5	36.66	31.66	4.21
T6	25.00	21.66	1.75
CD ($p<0.05$)	7.64	9.36	0.92

(T0: Control; T1: Scarification with concentrated sulfuric acid (50%); T2: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (40 days); T3: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (50 days); T4: Scarification with concentrated sulfuric acid (50%) + Cold stratification (60 days); T5: Scarification with concentrated sulfuric acid (50%) + Cold stratification (70 days); T6: Mechanical scarification with hammer)

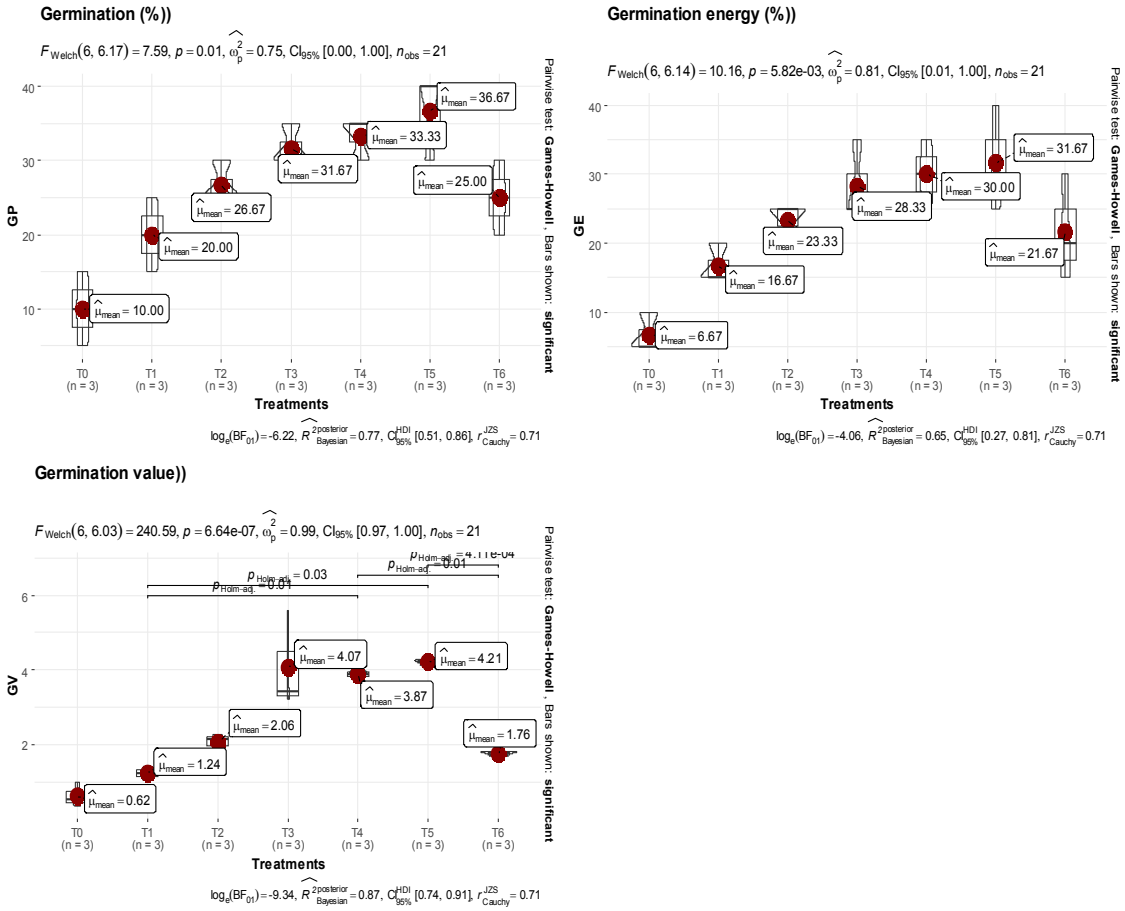


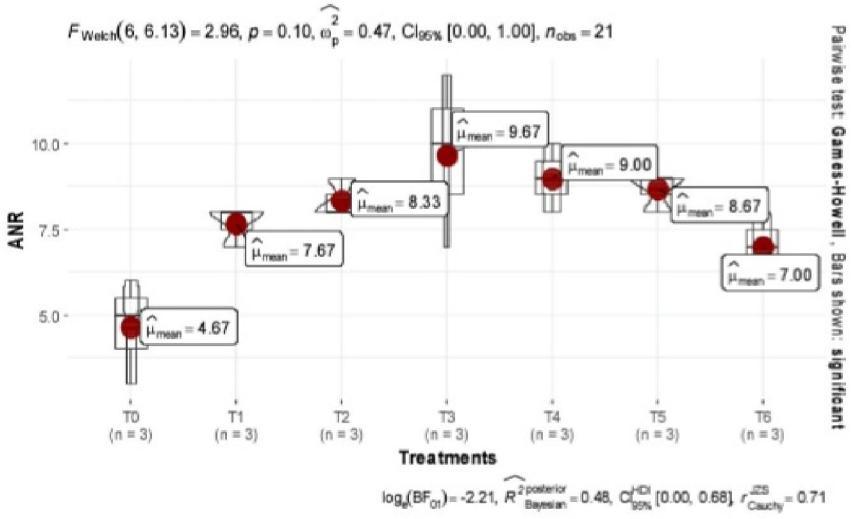
Fig 4: GG Stat plot for Germination percentage, Germination energy and Germination value

Table 37: Effect of seed scarification and stratification on Growth behavior of Hawthorn, *Crataegus songarica*

Parameters Treatments	Length of root (cm)	Average number of roots	Seedling height (cm)	Vigour index	Total Leaf area (cm^2)
T0 (Control)	1.55	4.66	5.64	56.40	23.21
T1	3.20	7.69	8.50	166.91	23.96
T2	3.47	8.33	9.41	250.18	24.37
T3	5.69	9.66	12.00	379.58	24.59
T4	4.66	9.00	12.17	404.10	25.37
T5	4.77	8.66	14.37	526.26	27.71
T6	3.53	7.00	11.47	287.78	25.53
CD ($p<0.05$)	0.64	2.26	1.39	80.92	1.36

(T0: Control; T1: Scarification with concentrated sulfuric acid (50%); T2: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (40 days); T3: Scarification with concentrated sulfuric acid (50%)+ Cold stratification (50 days); T4: Scarification with concentrated sulfuric acid (50%) + Cold stratification (60 days); T5: Scarification with concentrated sulfuric acid (50%) + Cold stratification (70 days); T6: Mechanical scarification with hammer)

Average number of roots))



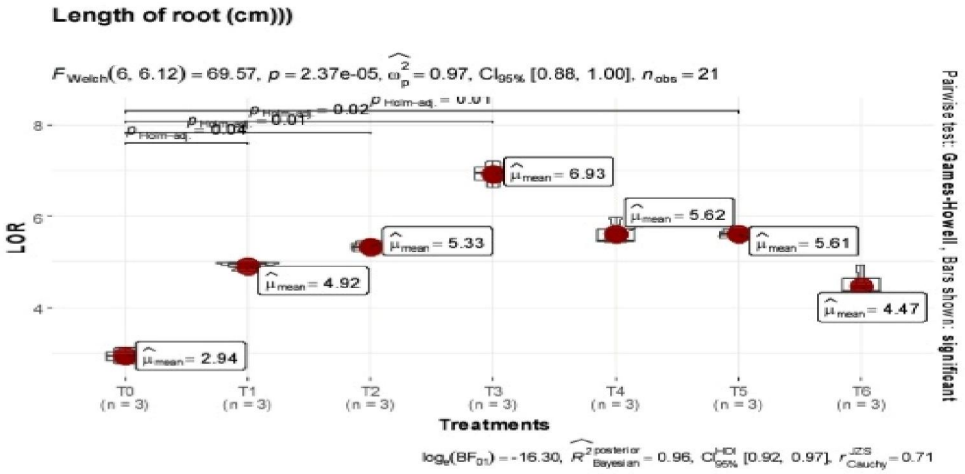


Fig 5: GG Stat plot for average number of roots length of root

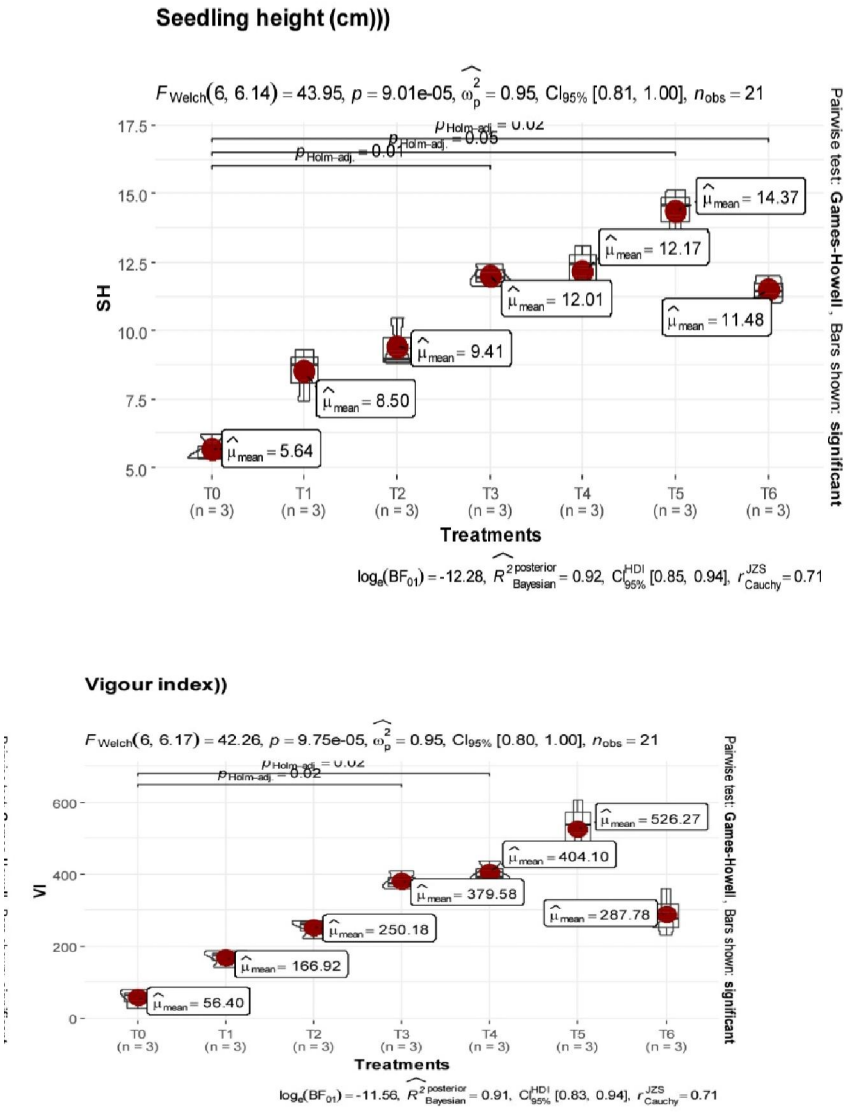


Fig 6: GG Stat plot for seedling height and vigour index

A **B**

Plate V: Propagation of *Crataegus songarica* through seeds. A. Germination B. Rooting C. Seedlings of *Crataegus songarica*

4.2.2 Propagation of *Crataegus songarica* through cuttings (Year 2021 and 2022)

Studies were conducted to propagate Hawthorn (*Crataegus songarica*) through cuttings. Prior to planting, these cuttings were treated with IBA and NAA. The effects of different concentrations of IBA and NAA (1000, 2000, 3000, 4000, 5000, and 6000 ppm) were examined and compared to control, in which the cuttings were treated with distilled water.

Sprouting percentage

The data presented in the table 38 shows that different concentrations of IBA and NAA had a significant effect on the sprouting percentage. Cuttings treated with IBA at a concentration of 4000 ppm (T4) showed the highest sprouting percentage of 93.33%. This was followed by IBA at 5000 ppm (86.66%), IBA at 2000 ppm and NAA at 4000 ppm (both 85.00%), IBA at 6000 ppm and NAA at 3000 ppm (both 83.33%), IBA at 1000 ppm and NAA at 5000 ppm (both 81.66%). Cuttings treated NAA at 2000 ppm showed sprouting percent of 78.77% and NAA at 1000 ppm (76.77%). The lowest sprouting percentage of 75.00% was recorded in the control (T0), which was maintained by treating cuttings with distilled water (Fig 7). It was further revealed that T2 (IBA 2000 ppm) remained statistically at par with T3 (IBA 3000 ppm), T6 (IBA 6000 ppm) remained statistically at par with T1 (IBA 1000 ppm) and T9 (NAA 1000 ppm) remained statistically at par with T10 (NAA 4000 ppm).

Rooting percentage

The data presented in the table 38 shows that different concentrations of IBA and NAA had a significant effect on rooting percentage. Cuttings treated with IBA at a concentration of 4000 ppm (T4) showed the highest rooting percentage of 76.66%. This was followed by T5 (IBA at 5000 ppm) with a recorded rooting percentage of 73.33% and IBA at 6000 ppm (70.00%). IBA at 3000 ppm (T3) recorded rooting percentage of 68.33%, IBA at 2000 ppm

(65.00%), NAA at 4000 ppm (61.66%), NAA at 3000 ppm (58.33%). Cuttings treated with IBA at 1000 ppm (T1) recorded rooting percentage of 56.66%. T1 was found statistically at par with NAA at 5000 ppm (56.00%) and NAA at 6000 ppm (55.00%). Furthermore, NAA at 2000 ppm showed rooting of 53.33% and NAA at 1000 ppm (50.00%). The lowest rooting percentage of 26.66% was recorded in the control (T0), which was maintained by treating cuttings with distilled water (Fig 7). It was further revealed that T1 (IBA 1000 ppm) remained statistically at par with T9 (NAA 3000 ppm), T11 (NAA 5000 ppm) and T12 (NAA 6000 ppm).

Average number of roots per cutting

The data presented in the table 38 indicates a significant difference in the number of roots observed in the cuttings, with regards to the application of IBA and NAA. The treatments had a considerable impact on the average number of roots. Notably, the cuttings treated with an IBA concentration of 4000 ppm (T4) showed the highest average number of roots, which amounted to 17.33. T4 (IBA 4000 ppm) was found statistically at par with 3000 ppm of IBA, recording an average of 16.66 roots. Cuttings treated with 5000 ppm of IBA showed an average of 14.33 roots and with 400 ppm of NAA had an average of 14.00 roots. The trend continued with decreasing average numbers of roots for the cuttings treated with 2000 ppm of IBA (T2) recorded 13.22 average number of roots. T2 was found statisticall at par with 3000 ppm of NAA (12.93), 6000 ppm of IBA (12.33), 2000 ppm of NAA (11.00). T9 (5000 ppm of NAA) recorded average number number of roots of 8.66. T9 was found statistically at par with 1000 ppm of IBA (8.33) and 6000 ppm of NAA (7.63). The lowest average number of roots, amounting to 5.66, was observed in the cuttings treated with distilled water (control) (Fig 7). It was further observed that T3 (IBA 3000 ppm) remained statistically at par with T2 (IBA 2000 ppm), T6 (IBA 6000 ppm) remained statistically at par with T5 (IBA 5000 ppm), T8 (NAA 2000 ppm) remained statistically at par with T9 (NAA

3000 ppm) and T11 (NAA 5000 ppm) remained statistically at par with T12 (NAA 6000 ppm).

Average root length (cm)

The data presented in the table 38 shows that different concentrations of IBA and NAA had a significant effect on average root length. Cuttings treated with IBA at a concentration of 4000 ppm (T4) showed the highest average root length of 11.03 cm followed by T4 (IBA 4000 ppm) with average root length of 8.93 cm, IBA at 2000 ppm (8.43 cm) and IBA at 1000 ppm (7.96 cm). Cuttings treated with IBA at 5000 ppm (T5) showed average root length of 6.56 cm. T5 was found statistically at par with NAA at 4000 ppm (6.43 cm), NAA at 3000 ppm (6.26 cm) and NAA at 2000 ppm (6.00 cm). Cuttings treated with IBA at 6000 ppm (T6) showed an average root length of 5.93 cm. T6 was found statistically at par with NAA at 1000 ppm (5.87 cm), NAA at 5000 ppm (5.80 cm) and NAA at 6000 ppm (5.53 cm). The lowest average number of roots (3.63 cm) was recorded in the control (T0), which was maintained by treating cuttings with distilled water (Fig 8). It was further revealed that T1 (IBA 1000 ppm) remained statistically at par with T2 (IBA 2000 ppm), T6 (IBA 6000 ppm) remained statistically at par with T7 (NAA 1000 ppm) and T11 (NAA 5000 ppm) remained statistically at par with T12 (NAA 6000 ppm).

Collar diameter of leading shoot (mm)

Collar diameter of leading shoot was significantly affected by treatments. Cuttings treated with IBA concentration 4000 ppm (T4) recorded highest collar diameter of 7.03 mm. Cuttings treated with IBA at 3000 ppm (T3) showed collar diameter of 6.22 mm followed by IBA at 2000 ppm (5.93 mm) and IBA at 1000 ppm (5.67 mm). Cuttings treated with NAA at 4000 ppm (T10) recorded collar diameter of leading shoot of (5.24 mm), IBA at 5000 ppm (4.97 mm), NAA at 3000 ppm (4.89 mm), NAA at 2000 ppm (4.78 mm), NAA at 5000 ppm (4.61 mm). Cuttings treated with IBA at 6000 ppm (T6) recorded collar diameter of

leading shoot of 4.55 mm, NAA at 1000 ppm (4.37 mm) and NAA at 6000 ppm (4.25 mm). Lowest collar diameter of leading shoot (3.82 mm) was recorded in control (Fig 8). It was further revealed that T6 (IBA 6000 ppm) remained statistically at par with T7 (NAA 1000 ppm) and T8 (NAA 2000 ppm) remained statistically at par with T9 (NAA 3000 ppm).

Total Leaf area (cm^2)

The data presented in the table 39 shows the effect of different concentrations of IBA and NAA on total leaf area. Cuttings treated with IBA at a concentration of 4000 ppm (T4) showed the highest leaf area of 28.68 cm^2, which was statistically at par with IBA at 3000 ppm (28.17 cm^2). Cuttings treated with IBA at 5000 ppm (T5) showed total leaf area of 26.71 cm^2, which was statistically at par with with IBA at 2000 ppm (26.46 cm^2). Cuttings treated with NAA at 4000 ppm showed total leaf area of 26.03 cm^2, which was statistically at par with IBA at 1000 ppm (25.93 cm^2), IBA at 6000 ppm (25.58 cm^2) and NAA at 3000 ppm (25.21 cm^2). Cuttings treated with NAA at 2000 ppm showed total leaf area of 25.24 cm^2 followed by NAA at 1000 ppm (24.28 cm^2), NAA at 5000 ppm (25.13 cm^2) and NAA 6000 ppm (24.24 cm^2). The lowest total leaf area (24.12 cm^2) was recorded in control (T0) (Fig 10).

Plant height (cm)

The data presented in table 39 showed that average height of plant (cm) was significantly influenced by IBA and NAA treatments. Cuttings treated with IBA concentration 4000 ppm showed maximum plant height of (27.53 cm) which was significantly different from plant height in other treatments. Cuttings treated with IBA at 3000 ppm showed plant height of 24.66 cm. Cuttings treated with IBA at 2000 ppm (T2) showed plant height of 21.83 cm followed by IBA at 5000 ppm (20.43 cm), NAA at 4000 ppm (19.06 cm) and IBA at 1000 ppm (19.00 cm). Cuttings treated with IBA at 6000 ppm showed plant height of 18.40 cm, which was statistically at par with NAA at 3000 ppm (18.26 cm) and NAA at

2000 ppm (17.90 cm). Cuttings treated with NAA at 1000 ppm showed plant height of 16.83 cm, NAA at 5000 ppm (15.40 cm) and NAA 6000 ppm (14.53 cm). Lowest plant height (13.10 cm) was recorded in control (T0) which was maintained by treating cuttings with distilled water (Fig 8).

Table 38: Effect of Growth Hormones on Rooting in *Crataegus songarica*

Treatment Parameter	Sprouting (%)	Rooting (%)	Average no. of roots per cutting	Average root length (cm)
Control	75.00 (8.65)	26.66 (5.15)	5.66	3.63
T1	81.66 (9.03)	56.66 (7.52)	8.33	7.96
T2	85.00 (9.21)	65.00 (8.05)	13.33	8.43
T3	86.66 (9.30)	68.33 (8.26)	16.66	8.93
T4	93.33 (9.66)	76.66 (8.75)	17.33	11.03
T5	86.66 (9.30)	73.33 (8.55)	14.33	6.56
T6	83.33 (9.12)	70.00 (8.35)	12.33	5.93
T7	76.77 (8.75)	50.00 (7.06)	7.00	5.87
T8	78.77 (8.84)	53.33 (7.29)	11.00	6.00
T9	83.33 (9.12)	58.33 (7.63)	12.93	6.26
T10	85.00 (9.21)	61.66 (7.85)	14.00	6.43
T11	81.66 (9.03)	56.00 (7.62)	8.66	5.80
T12	78.33 (8.80)	55.00 (7.19)	7.63	5.53
CD ($p<0.05$)	2.59	3.26	2.52	0.97

Control: Distilled water, T1@ IBA1000 ppm, T2@ IBA 2000 ppm, T3 @IBA 3000 ppm, T4@IBA 4000 ppm, T5@IBA 5000 ppm, T6@IBA 6000 ppm, T7@NAA 1000 ppm, T8@NAA 2000 ppm, T9@NAA 3000 ppm, T10@NAA 4000 ppm, T11@NAA 5000 ppm, T12@NAA 6000 ppm

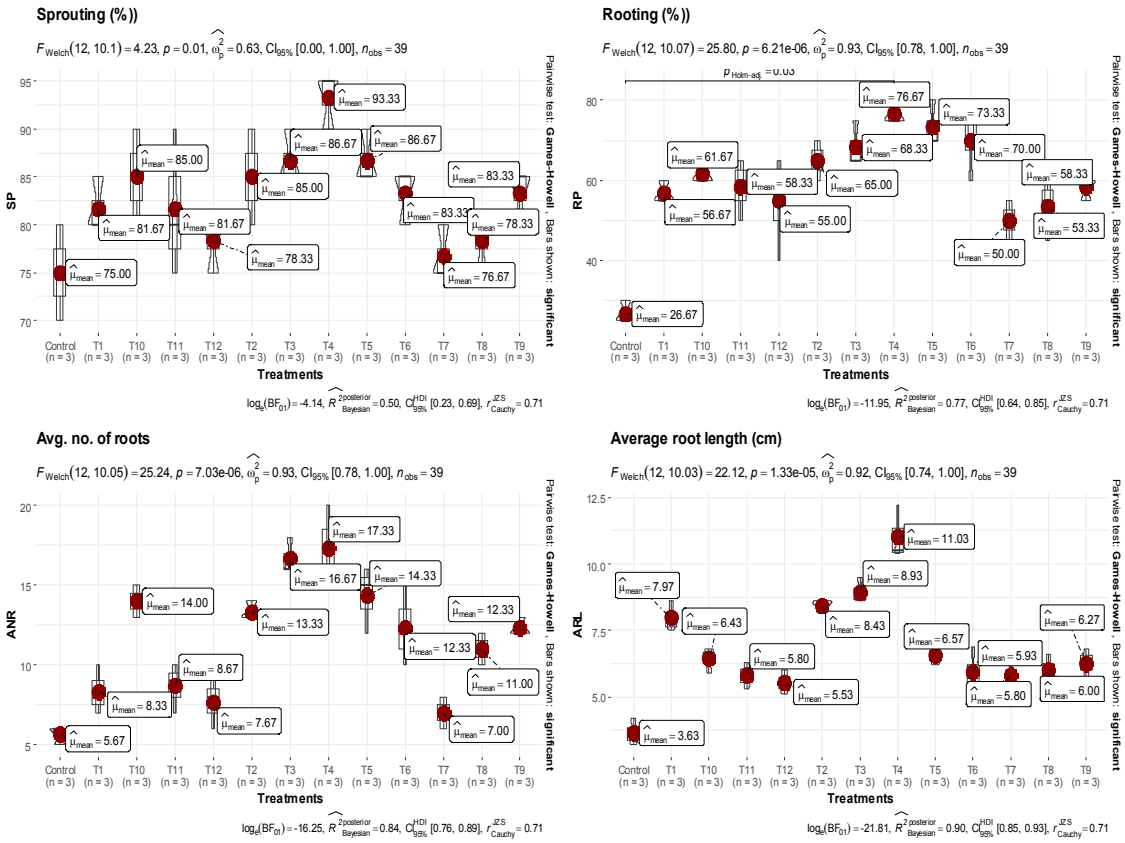


Fig 7: GG Stat plot for Sprouting (%), Rooting (%), Average number of roots and Average root length (cm)

Table 39: Effect of Growth Hormones on Growth in *Crataegus songarica*

Treatment Parameter	Collar diameter of leading shoot (mm)	Leaf area (cm^2)	Plant height (cm)
Control	3.82	24.61	13.10
T1	5.67	25.93	19.00
T2	5.93	26.46	21.83
T3	6.22	28.17	24.66
T4	7.03	28.68	27.53
T5	4.97	26.71	20.43
T6	4.55	25.58	18.40
T7	4.37	24.28	16.83
T8	4.78	25.04	17.90
T9	4.89	25.21	18.26
T10	5.24	26.03	19.06
T11	4.61	25.13	15.40
T12	4.25	24.24	14.53
CD ($p<0.05$)	0.25	0.97	0.87

Control: Distilled water, T1@ IBA1000 ppm, T2@ IBA 2000 ppm, T3 @IBA 3000 ppm, T4@IBA 4000 ppm, T5@IBA 5000 ppm, T6@IBA 6000 ppm, T7@NAA 1000 ppm, T8@NAA 2000 ppm, T9@NAA 3000 ppm, T10@NAA 4000 ppm, T11@NAA 5000 ppm, T12@NAA 6000 ppm

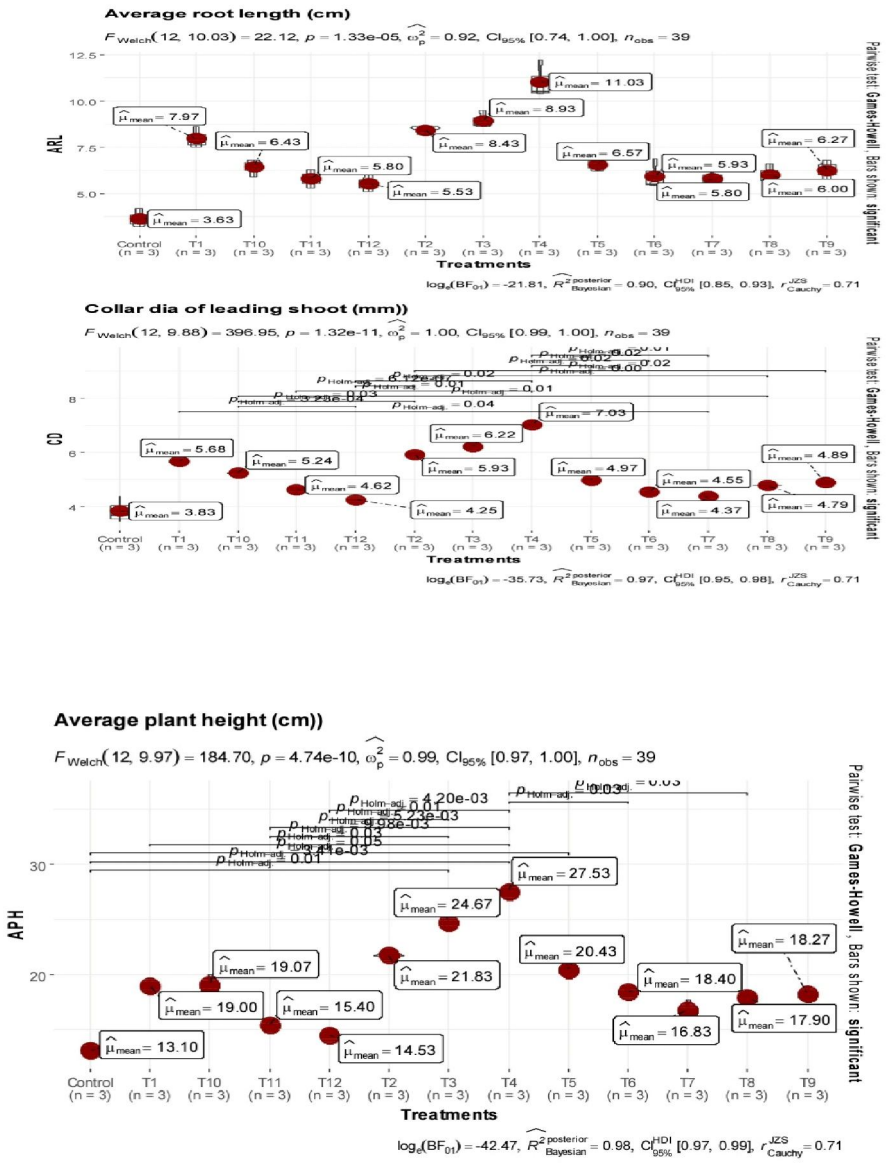
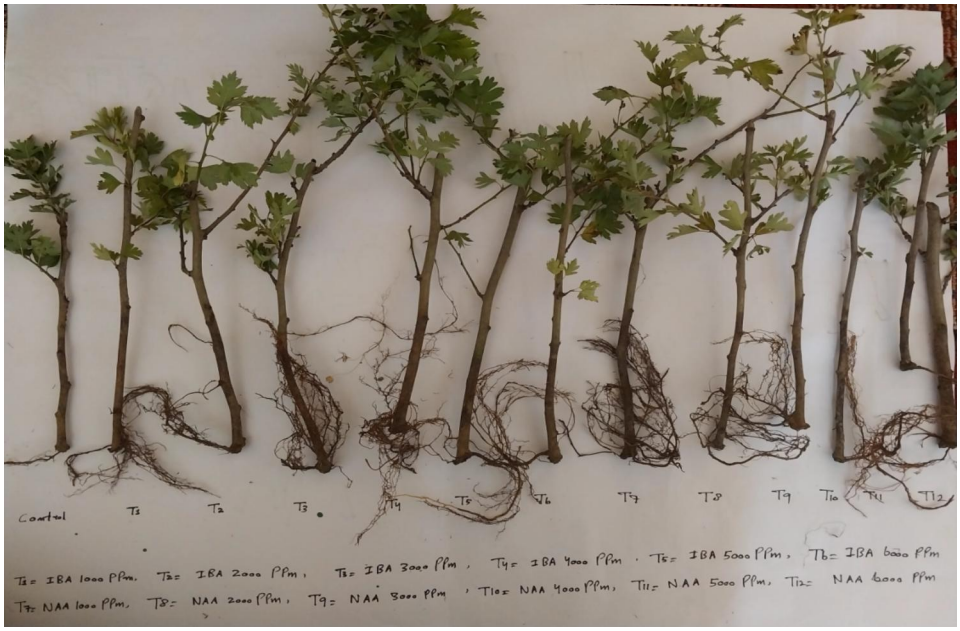


Fig 8: GG Stat plot for Average number of root length (cm), Collar diameter of shoot (mm) And Average plant height (cm)



A

B

Plate VI: Propagation of *Crataegus songarica* through cuttings. A. Rooting of cuttings, B. Experimental Trial

4.3 To study the chemical profiling of *Crataegus songarica*

Studies were conducted to study total phenol content, flavonoid content and antioxidant activity in fruits and leaves of Hawthorn, *Crataegus songarica* in Kashmir Himalays. For this various fruit and leave samples were collected from five different sites across Kashmir Himalayas. These sites includes Site 1 (Malhar Ganderbal), Site 2 (Babareshi Gulmarg), Site 3 (Dachigam National Park), Site 4 (Ajas Bandipora) and Site 5 (Shikergah Tral). All the collected samples were than evaluated for total phenol content, flavonoid content and antioxidant activity for both fruit and leave.

4.3.1 Total phenols, Total flavonoids and antioxidant activity in Hawthorn, *Crataegus songarica* fruits

Studies conducted with Hawthorn leaves revealed that site 1 (Malhar Ganderbal) recorded highest phenol content (38.28 mg GAE/g DW). Samples collected from site 5 (Shikergah Tral) recorded total phenol content of 34.10 mg GAE/g DW, which was found statistically at par with site 2 (Babareshi Gulmarg), with total phenol content of 34.09 mg GAE/g DW and site 4 (Ajas Bandipora), with total phenol content of 33.68 mg GAE/g DW in. Lowest total phenol content (33.39 mg GAE/g DW) was observed in samples collected from site 3 (Dachigam National Park).

Total flavonoids were found maximum (5.71 mg QUE/g DW) in samples collected from Site 2 (Babareshi Gulmarg), which was followed by Site 1 (Malhar Ganderbal), with total flavonoid content of 4.82 mg QUE/g DW) and in site 3 (Dachigam National park), with total flavonoid content of 4.53 mg QUE/g DW. Site 5 (Shikergah Tral) recorded total flavonoid content of 3.62 mg QUE/g DW. Lowest total flavonoid content 3.51 mg QUE/g DW was observed in samples collected from site 4 (Ajas Bandipora).

Antioxidant activity was recorded highest with a value of 1.71 mmol Fe++/g DW observed in samples collected from site 1 (Malhar Ganderbal). This

was followed by 1.20 mmol Fe++/g DW in site 2 (Babareshi Gulmarg), which was statistically at par with site 3 (Dachigam National Park), with antioxidant activity of 0.92 mmol Fe++/g DW. Furthermore antioxidant activity was recorded 0.69 mmol Fe++/g DW in site 5 (Shikergah Tral). Lowest antoxidant acitivity (0.64 mmol Fe++/g DW) was in sample collected from site 4 Ajas Bandipora). Furthermore, mean TSS content of 14.07 Brix was observed in fruits with site 1 (Malhar Ganderbal) recored maximum TSS content of 16.50 Brix and minimum in case of site 4 (Ajas Bandipora) i,e 12.40 Brix (Table 40, Fig 9).

4.3.2 Total phenols, Total flavonoids and antioxidant activity in Hawthorn, *Crataegus songarica* leaves

Studies conducted revealed that total phenol content varied significantly with site 1 (Malhar Ganderbal) recorded highest phenol content (28.28 mg GAE/g DW). Site 2 (Babareshi Gulmarg) recorded total phenol content of 27.27 mg GAE/g DW, which was statistically at par with site 3 (Dachigam National park), with total phenol content of 26.48 mg GAE/g DW. Site 4 (Ajas Bandipora) recorded total phenol content of 26.25 mg GAE/g DW. Lowest total phenol content (25.70 mg GAE/g DW) was observed in samples collected from Site 5 (Shikergah Tral).

Total flavonoid content was found maximum (7.87 mg QUE/g DW) in samples collected from Site 2 (Babareshi Gulmarg), which was found statistically at par with Site 1 (Malhar Ganderbal), with total flavonoid content of 7.41 mg QUE/g. Site 3 (Dachigam National park) recorded total flavonoid content of 7.15 mg QUE/g DW. Site 4 (Ajas Bandipora) recorded flavonoid content of 6.58 mg QUE/g DW. Lowest total flavonoid content 6.41 mg QUE/g DW was observed in samples collected from site 5 (Shikergah Tral).

Antioxidant activity was recorded highest 0.93 mmol Fe++/g DW in samples collected from site 1 (Malhar Ganderbal), which was found statistically at par with site 5 (Shikergah Tral), with a antioxidant activity of 0.90 mmol Fe++/g

DW, site 4 (Ajas Bandipora), with a antioxidant activity of 0.91 mmol Fe++/g DW and in site 2 (Babareshi Gulmarg), with an antioxidant activity of 0.88 mmol Fe++/g DW. The lowest antioxidant activity (0.75 mmol Fe++/g DW) was observed in samples collected from site 3 (Dachigam National Park) (Table 41, Fig 10).

Investigations conducted also revealed that total phenol content and antoxidant activity is more in hawthorn fruits than in leaves. However, total flavonoid content is more in leaves as compared to fruits (Table 42).

Table 40: Total Phenol, Flavonoid content and Anti oxidant activity in *Crataegus songarica* fruits

Sites	Altitude (m)	Latitude	Longitude	Total Phenol content (mg GAE/g DW)	Total Flavonoids (mg QUE/g DW)	Anti-oxidant Activity (mmol Fe++/g DW)	TSS content (Brix %)
Malhar Ganderbal	1850	34.33° N	74.46° E	38.28	4.82	1.71	16.50
Babareshi, Gulmarg	2050	34.05° N	74.38° E	34.09	5.71	1.20	13.50
Dachigam National Park	1800	34.07° N	74.61° E	33.39	4.53	0.92	13.78
Ajas Bandipora	1750	34.37° N	74.67° E	33.68	3.51	0.64	12.40
Shikergah Tral	1900	33.86° N	75.10° E	34.10	3.62	0.69	14.20
CD ($p<0.05$)	----	--	---	2.10	0.44	0.37	1.64

Table 41: Total Phenol, Flavonoid content and Anti oxidant activity in *Crataegus songarica* Leaves

Sites	Altitude (m)	Latitude	Longitude	Total Phenol content (mg GAE/g DW)	Total Flavonoids (mg QUE/g DW)	Anti-oxidant Activity (mmol Fe++/g DW)
Malhar Ganderbal	1850	34.33° N	74.46° E	28.58	7.41	0.93
Babareshi, Gulmarg	2050	34.05° N	74.38° E	27.07	7.87	0.88
Dachigam National Park	1800	34.07° N	74.61° E	26.48	7.15	0.75
Ajas Bandipora	1750	34.37° N	74.67° E	26.25	6.58	0.91
Shikergah Tral	1900	33.86° N	75.10° E	25.70	6.41	0.90
CD ($p<0.05$)	----	--	---	0.93	0.48	0.06

Table 42: Comparison Level of total phenols content, total flavonoids, and antioxidant activity in fruits and Leaves of *Crataegus songarica*.

Site	Site 1		Site 2		Site 3		Site 4		Site 5		Observation
Parameter	Fruit	Leave	Fruit	Leave	Fruit	Leave	Fruit	Leave	Fruit	Leave	
Total Phenol content (mg GAE/g DW)	38.28	28.58	34.09	27.07	33.39	26.48	33.68	26.25	34.10	25.70	More in Fruit
Total Flavonoids (mg QUE/g DW)	4.82	7.41	5.71	7.87	4.53	7.15	3.51	6.58	3.62	6.41	More in Leave
Anti-oxidant Activity (mmol Fe++/g DW)	1.71	0.93	1.20	0.88	0.92	0.75	0.64	0.91	0.69	0.90	More in Fruit

Site 1: Malhar Ganderbal; Site 2: Babareshi, Gulmarg, Site 3; Dachigam National Park, Site 4; Ajas Bandipora;

Site 5: Shikergah Tral.

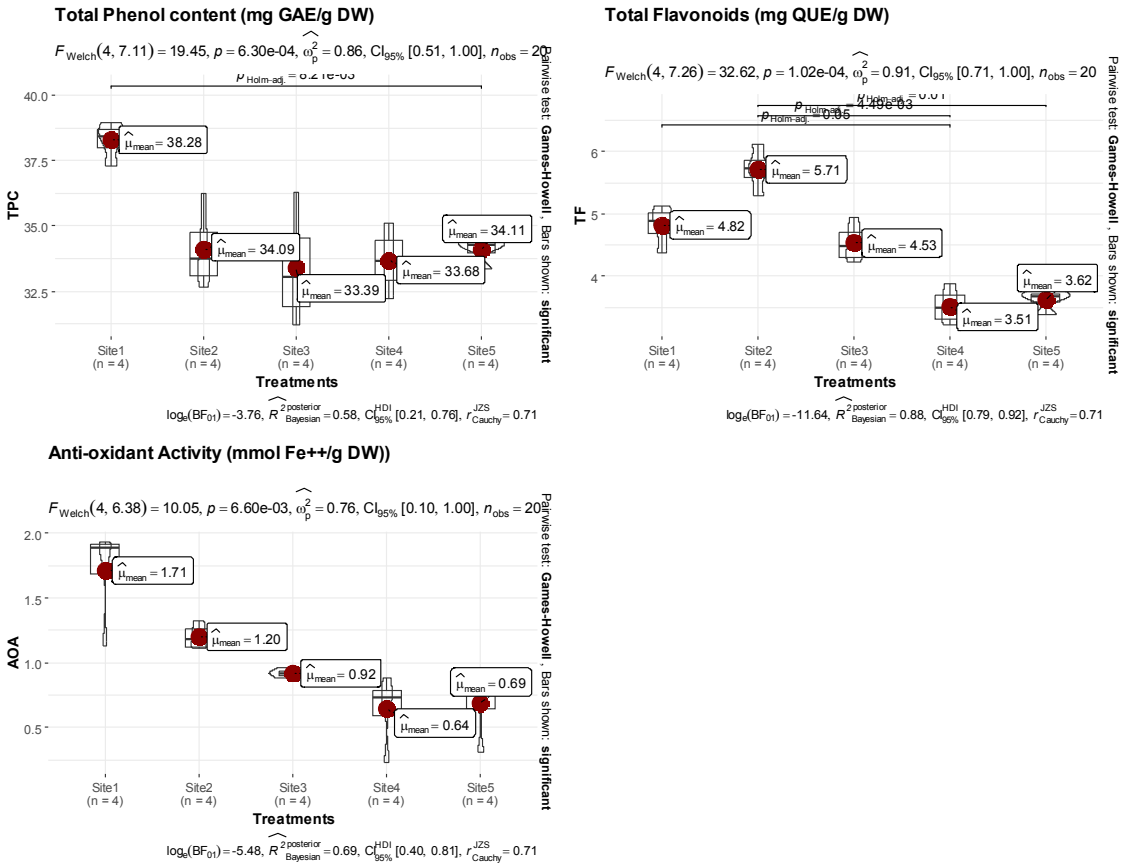


Fig 9: GG Stat Plot for Total phenolic content, Total Flavonoids and Anti-oxidant activity in *Crataegus songarica* fruits

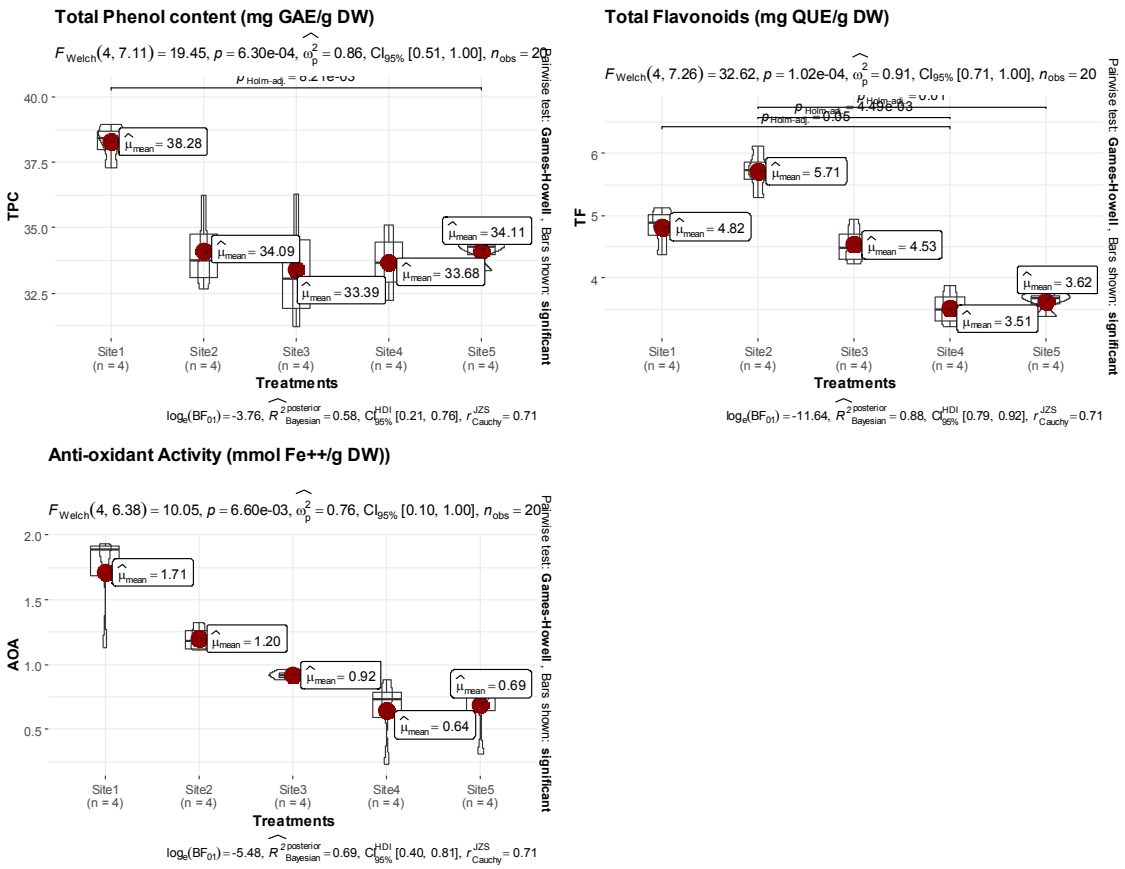
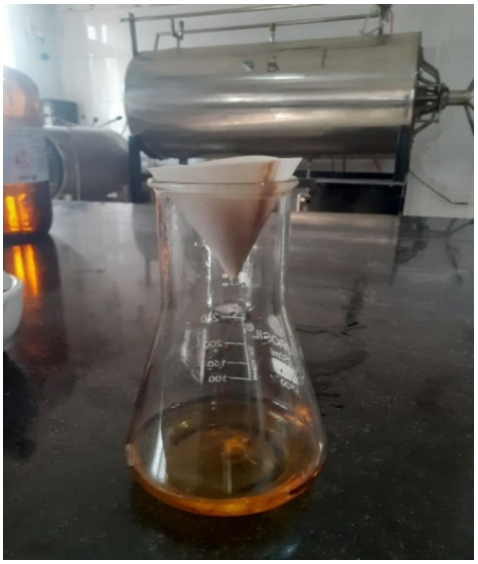


Fig 10: GG Stat Plot for Total phenolic content, Total Flavonoids and Anti-oxidant activity in *Crataegus songarica* Leaves



A **B**

Plate VII: Chemical profiling of *Crataegus songarica.* A. Leaf Extract, B. Fruit Extract, C. Estimation of TSS content, D. Laboratory work

Chapter 5

DISCUSSION

The results obtained during present investigation on **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** have been discussed in this chapter with the support of research work done earlier.

5.1 To study phenology and population ecology of *Crataegus songarica*

5.1.1 Phenology of *Crataegus songarica*

This study examines the phenology of *Crataegus songarica* over two consecutive years, 2021 and 2022. The observations from 2021 revealed that bud set occurred in the third week of February, followed by bud bursting in the fourth week of March. By the first week of April, the leaves were fully open, and flowering commenced in the fourth week of April, lasting until the fourth week of May, with the peak occurring in the second week of May. Fruiting initiation was observed in the fourth week of July, while fruit fall started in the second week of September and lasted until the third week of October. Leaf tint appeared in the third week of September, and leaf fall began in the fourth week of September, continuing until the first week of November. The entire phenophase cycle of Crataegus songarica in 2021 lasted 9 months and 3 weeks. The observations from 2022 indicate that bud set began in the second week of February, followed by bud bursting in the third week of March. By the fourth week of March, the leaves were fully open, and flowering commenced in the third week of April, lasting until the third week of May, with the peak occurring in the first week of May. Fruiting initiation was observed in the third week of July, while fruit fall started in the first week of September and lasted until the third week of October. Leaf tint appeared in the second week of September, and leaf fall began in the third week of September, continuing until the fourth week of October. The entire phenophase cycle of *Crataegus songarica* in 2022 lasted 9 months and 3 weeks. By comparing

these two years, we can gain insights into the variations in the phenological patterns of *Crataegus songarica* and better understand the impact of environmental factors on its life cycle.

The present study unveils the early phenological emergence of events in *Crataegus songarica* during the year 2022, potentially attributed to warmer temperatures compared to 2021 in the study area. Temperature plays a crucial role in shaping the phenological patterns of trees, influencing various phenophases such as bud burst, leaf emergence, flowering, fruiting, leaf color change, and leaf fall. Understanding the influence of temperature on tree phenology is crucial for predicting and adapting to potential shifts in the timing of these significant life cycle events. The increased temperate in 2022 as compared to 2021 resulted in early emergence of phonological events in *Crataegus songarica* (Annexure I). Numerous researchers have examined tree phenology worldwide, including Singh and Negi (2018), Nanda *et al*., (2017), Mir *et al*., (2016), Dantas *et al*., (2016), Kumar *et al*., (2014) and Bajpal *et al*., (2012). Singh and Negi (2018) focused on the phenology of tree line species, namely *Abies spectabilis*, *Betula utilis*, *Quercus semecarpifolia* and *Rhododendron arboreum*. They found that leaf bud-break occurred in May for all the species, with a delay of approximately two months in leaf initiation for tree line species compared to mid-altitude tree species. Additionally, the study revealed slower leaf expansion within one month of leafing in tree line species than in mid-altitude species. It is anticipated that with increasing rates of warming, the phenological behavior of tree line species will undergo substantial changes, ultimately affecting ecosystem properties. Mir *et al*., (2016) investigated the phenology of Himalayan birch (*Betula utilis*) along different altitudinal gradients in Kashmir Western Himalayas. They observed phenological events across the altitudinal gradient in distinct ecological settings at Sindh and Tangmarg forest divisions in Kashmir Himalayas. The study revealed high synchrony throughout the altitudinal gradients, particularly for bud set, bud burst, peak flowering, and seed maturation. All phenological events commenced

earlier at lower elevations compared to higher elevations. The timing of phenophases along the altitude was influenced by the timing of snow-melt, which typically triggers early phenological changes in the northern alpine habitats. Kumar *et al*., (2014) explored the phenology of different tree species in South Gujarat. Their findings showed that vegetative growth, starting with leaf flushes in March to April, was completed by May in 72.4% of the species studied. Leaf drop and simultaneous leafing occurred during the warm-day period of the year. Approximately 68.0% of the species exhibited multiple leafing. In deciduous trees, flower (17.2%) and fruit formation (3.4%) occurred in March, a month earlier than in evergreen trees. Furthermore, fruit maturation between March and June was again advanced by one month in deciduous species.

In summary, this study highlights the early phenological emergence of events in *Crataegus songarica* in 2022, likely due to warmer temperatures compared to the previous year. Temperature plays a vital role in shaping tree phenology, affecting various phenophases. Understanding the impact of temperature on tree phenology is essential for predicting and adapting to potential shifts in the timing of these crucial life cycle events. Previous research conducted by Singh and Negi (2018), Mir *et al*., (2016), and Kumar *et al*., (2014) on tree phenology in different species and locations provides valuable insights into the subject.

5.1.2 Population ecology of Hawthorn, *Crataegus songarica*

Associate Species of Hawthorn, *Crataegus songarica*

The forests of Kashmir Himalayas exhibit a diverse range of plant species that coexist with *Crataegus songarica*. A comprehensive survey identified a total of 34 species, comprising 11 trees, 6 shrubs, and 16 herbs. These species belong to 23 families, with Pinaceae, Fabaceae, Rosaceae, and Asteraceae emerging as the dominant families, each consisting of 3 species. Furthermore, Cannabaceae, Moraceae, Berberidaceae, and Poaceae were represented by 2 species each.

Simaroubaceae, Sapindaceae, Juglandaceae, Ulmaceae, Hamamelidaceae, Sambucaceae, Caprifoliaceae, Liliaceae, Hypericaceae, Lamiaceae, Malvaceae, Polygonaceae, Urticaceae, and Violaceae were represented by 1 species each.

To gain a comprehensive understanding of the distribution and prevalence of these species, the study incorporated data from various Forest divisions in the Kashmir Himalayas. Tables 3 and 4 present valuable information regarding the common names, families, local names, and the presence or absence of species across these divisions. The data obtained from this survey contribute to our knowledge of the plant diversity within the forests of the Kashmir Himalayas. The presence of a wide range of species from different families underscores the ecological richness and complexity of this region. Understanding the distribution patterns of these species can aid in conservation efforts, as it allows for targeted strategies to protect and preserve the unique flora of this area.

Population ecology and floristic diversity have been extensively studied by several researchers around the world. In the Batkote Block of the Pahalgam Range, Bhat (2017) reported a total of 59 plant species belonging to 37 families. Among these species, 11 were tree species, 10 were shrubs, and 38 were herbs. The dominant family in this area was Poaceae, represented by seven species. Similarly, Aijaz *et al.,* (2022) conducted a study in the Overa Wildlife Sanctuary of Kashmir and identified 37 plant species belonging to 25 families. Among them, 8 were tree species, 8 were shrub species, and 21 were herb species. The dominant family in this sanctuary was Asteraceae, with 4 species, followed by Pinaceae and Fabaceae, each with 3 species. Malvaceae, Poaceae, Polygonaceae, Rosaceae, and Sapindaceae were represented by two species each. Betulaceae, Dioscoreaceae, Berberidaceae, Caprifoliaceae, Juglandaceae, Simaroubaceae, Hamamelidaeae, Cupressaceae, Ranunculaceae, Lamiaceae, Phytolacaceae, Podophyllaceae, Solanaceae, Cannabaceae, Poaceae, Urticaceae, and Valerianaceae were represented by one species in each family. Praba *et* al., (2008) conducted a study in the foothill forests of the Garhwal Himalayas and identified 45 tree species and

31 shrub species. In the forest area of Shivapuri National Park, Pandey and Bajracharya (2010) recorded a total of 18 tree species belonging to 13 families. Shah and Rozina (2010), in their study in Dheri Baba Hill Gohati, reported the identification of 72 plant species belonging to 23 families. In another study on the floristic diversity of the Overa Wildlife Sanctuary, Mugloo *et al*., (2021) identified 53 plant species from 35 families. Among these species, 9 were trees, 8 were shrubs, and 36 were herbs. Poaceae was the dominant family with 7 species, followed by Pinaceae, Rosaceae, and Fabaceae, each with four species. Overall, these studies contribute to our understanding of population ecology and floristic diversity in various regions. The findings highlight the richness and composition of plant species across different families, emphasizing the importance of conservation efforts to protect and preserve these diverse ecosystems.

Phytosociological attributes of plant species

The data presented in Tables 4, 5, and 6 for the Sindh Forest Division reveal the presence of seven tree species, six shrub species, and 14 herb species, including Hawthorn (*Crataegus songarica*). Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 82.58, followed by *Juglans regia* (45.19), *Ailanthus altissima* (40.07), *Robinia pseudoacacia* (37.37), *Aesculus indica* (33.34), and *Celtis australis* (31.61). The lowest IVI was observed for Morus nigra (29.84) (Table 5). Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 61.79, followed by *Viburnum grandiflorum* (48.45), *Parrotia jacquemontiana* (43.56), *Rosa weibaana* (39.61), *Indigofera heterantha* (36.83), and *Sambucus wightiana* (35.68). The lowest IVI was observed for Berberis lyceum (34.18) (Table 6). Among the herb species, the maximum IVI was observed for *Cynodon dactylon* (32.24), followed by *Fragaria vesca* (31.06) and *Malva neglecta* (24.10) (Table 7). The lowest IVI was observed for *Podophyllum hexandrum* (13.00).

The data presented in Tables 7, 8, and 9 for the Bandipora Forest Division reveal the presence of six tree species, five shrub species, and 11 herb species, including Hawthorn (*Crataegus songarica*). Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 100.99, followed by *Juglans regia* (50.12), *Robinia pseudoacacia* (45.56), *Aesculus indica* (38.51), and *Morus nigra* (33.39). The lowest IVI was observed for *Morus alba* (31.45) (Table 7). Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 69.69, followed by *Parrotia jacquemontiana* (50.01), *Rosa weibaana* (49.55), *Indigofera heterantha* (47.96), and *Viburnum grandiflorum* (42.62). The lowest IVI was observed for *Berberis lyceum* (40.17) (Table 8). Among the herb species, the maximum IVI was observed for *Malva neglecta* (33.33), followed by *Taraxacum officinale* (32.17), *Cynodon dactylon* (31.68), and *Trifolium repens* (30.59) (Table 9). The lowest IVI was observed for *Viola odorata* (21.11).

The data presented in Tables 10, 11, and 12 for the Budgam Forest Division reveal the presence of seven tree species, five shrub species, and 13 herb species, including Hawthorn (*Crataegus songarica)*. Among the tree species in the Budgam Forest Division, the highest Importance Value Index (IVI) was observed for *Pinus wallichiana* with a value of 78.74, followed by *Abies pindrow* (65.35), *Juglans regia* (34.52), *Aesculus indica* (33.01), *Morus nigra* (30.89), and *Ailanthus altissima* (30.09). The lowest IVI was observed for *Robinia pseudoacacia* (27.80) (Table 10). Moving on to the shrub species, *Viburnum grandiflorum* was the dominant species with an IVI value of 58.62, followed by *Crataegus songarica* (55.53), *Parrotia jacquemontiana* (53.52), *Indigofera heterantha* (48.88), and *Sambucus wightiana* (41.94) (Table 11). The lowest IVI was observed for *Berberis lyceum* (41.51). Among the herb species in the Budgam Forest Division, *Fragaria vesca* had the maximum IVI of 34.89, followed by *Trifolium repens* (26.90), Mentha spicata (25.76), and *Artemisia absinthium* (25.33) (Table 12). The lowest IVI was observed for *Viola odorata* (16.50).

Moving on to the data presented in Tables 13, 14 and 15 for the Tangmarg Forest Division, we find the presence of seven tree species, five shrub species, and 14 herb species, including Hawthorn (*Crataegus songarica*). Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara* with a value of 85.91, followed by *Juglans regia* (47.21), *Robinia pseudoacacia* (34.99), *Celtis australis* (33.83), *Morus nigra* (33.51), and *Aesculus indica* (33.44) (Table 13). The lowest IVI was observed for *Ulmus villosa* (31.11). Among the shrub species in the Tangmarg Forest Division, *Crataegus songarica* was the dominant species with an IVI value of 74.72, followed by *Viburnum grandiflorum* (53.00), *Parrotia jacquemontiana* (48.00), *Indigofera heterantha* (43.04), and *Rosa weibaana* (41.31) (Table 14). The lowest IVI was observed for *Berberis lyceum* (39.93). Among the herb species, *Fragaria vesca* had the maximum IVI of 27.68, followed by *Mentha spicata* (25.67), *Trifolium repens* (25.47), and *Cynodon dactylon* (25.06) (Table 15). The lowest IVI was observed for *Fritillaria imperialis* (16.73).

The presented data in Tables 16, 17 and 18 regarding the Shopian Forest Division demonstrate the existence of five tree species, four shrub species, and 13 herb species, accompanied by Hawthorn, *Crataegus songarica.* Among the tree species, the highest Importance Value Index (IVI) was observed for *Cedrus deodara*, with a value of 92.47, followed by *Pinus walliachiana* (91.22) and *Robinia pseudoacacia* (45.80). The lowest IVI was recorded for *Juglans regia* (33.52) (Table 16). In terms of shrub species, the dominant species in the area was *Parrotia jacquemontiana*, with an IVI value of 76.66, followed by *Vibernum grandiflorum* (64.69), *Indigofera heterantha* (61.55), and *Berberis lyceum* (50.73). The lowest IVI was observed for *Crataegus songarica* (46.47) (Table 17). Among the herb species, the maximum IVI was recorded for *Cynodon dactylon* (34.46), followed by *Fragaria vesca* (31.70), *Urtica dioica* (27.09), and Malva neglecta (26.82). The lowest IVI was observed for *Podophyllum hexandrum* (10.71) (Table 18).

Furthermore, the data presented in Tables 19, 20 and 21 concerning the Anantnag Forest Division reveal the presence of six tree species, four shrub species, and 15 herb species, alongside Hawthorn, *Crataegus songarica*. Among the tree species, the highest Importance Value Index (IVI) was observed for *Abies pindrow*, with a value of 87.86, followed by *Pinus walliachiana* (78.47), *Aesculus indica* (40.52), *Juglans regia* (36.65), and *Robinia pseudoacacia* (32.23). The lowest IVI was recorded for *Ailanthus altissima* (24.27) (Table 19). Among the shrub species in the area, *Berberis lyceum* was the dominant species, with an IVI value of 72.08, followed by *Vibernum grandiflorum* (70.21), *Indigofera heterantha* (56.19), and *Parrotia jacquemontiana* (53.54). The lowest IVI was observed for *Crataegus songarica* (47.98) (Table 20). Regarding herb species, the maximum IVI was observed for *Fragaria vesca* (29.50), followed by *Taraxacum officinale* (24.69), *Malva neglecta* (24.00), and *Trifolium repens* (23.47). The lowest IVI was recorded for *Podophyllum hexandrum* (10.34) (Table 21).

The data presented in Tables 22, 23 and 24 regarding the Langate Forest Division reveal the presence of six tree species, three shrub species, and 12 herb species, alongside Hawthorn (*Crataegus songarica*). Among the tree species, the highest Importance Value Index (IVI) was observed for *Pinus walliachiana* with a value of 87.06, followed by *Cedrus deodara* (82.70), *Aesculus indica* (38.31), *Juglans regia* (32.60), and *Robinia pseudoacacia* (31.32). The lowest IVI was observed for *Ulmus villosa* (28.01) (Table 22). Among the shrub species in the area, *Crataegus songarica* was the dominant species with an IVI value of 85.07, followed by *Viburnum grandiflorum* (79.50) and *Parrotia jacquemontiana* (67.81). The lowest IVI was observed for *Indigofera heterantha* (67.62) (Table 23). Among the herb species, the maximum IVI was observed for *Fragaria vesca* (37.55), followed by *Taraxacum officinale* (30.44), *Artemisia absinthium* (29.84), and *Dactylis glomerata* (28.35). The lowest IVI was observed for *Podophyllum hexandrum* (13.12) (Table 24).

The data presented in Tables 25, 26 and 27 pertaining to the Kamraj Forest Division reveal the presence of six tree species, five shrub species, and 13 herb species, alongside Hawthorn (*Crataegus songarica*). Among the tree species, the highest Importance Value Index (IVI) was observed for *Pinus walliachiana* with a value of 75.48, followed by *Cedrus deodara* (69.96), *Abies pindrow* (61.62), *Robinia pseudoacacia* (33.15), and *Ailanthus altissima* (30.93). The lowest IVI was observed for *Morus nigra* (28.86) (Table 25). Among the shrub species in the area, *Viburnum grandiflorum* was the dominant species with an IVI value of 57.86, followed by *Indigofera heterantha* (53.96), *Berberis lycium* (53.02), *Crataegus songarica* (46.28), and *Rosa weibaana* (44.73). The lowest IVI was observed for *Parrotia jacquemontiana* (44.15) (Table 26). Among the herb species, the maximum IVI was observed for *Cynodon dactylon* (28.45), followed by *Trifolium repens* (26.97), *Fragaria vesca* (26.68), and *Conyza canadensis* (25.62). The lowest IVI was observed for *Fritillaria imperialis* (16.85) (Table 27).

The data presented in Tables 28, 29 and 30 regarding the Kehmil Forest Division reveal the presence of seven tree species, three shrub species, and 12 herb species, including Hawthorn (*Crataegus songarica*). Among the tree species, *Cedrus deodara* exhibited the highest Importance Value Index (IVI) with a value of 65.07, followed by *Pinus walliachiana* (61.11), *Abies pindrow* (56.00), *Ailanthus altissima* (35.22), *Aesculus indica* (31.28), and *Juglanas regia.* The lowest IVI was observed for *Morus alba* (21.02) (Table 28). Among the shrub species in the area, *Vibernum grandiflorum* dominated with an IVI value of 79.53, followed by *Parrotia jacquemontiana* (76.53), *Crataegus songarica* (72.41), *Indigofera heterantha* (71.53) and *Berberis lycium* (53.02). The lowest IVI was observed for *Berberis lycium* (53.02) (Table 29). Among the herb species, *Malva neglecta* exhibited the highest IVI (28.85), followed by *Cynodon dactylon* (28.63), *Trifolium repens* (28.17), and *Cannabis sativa* (27.21). The lowest IVI was observed for *Viola odorata* (19.31) (Table 30).

The data presented in Tables 31, 32 and 33 regarding the Baramulla Forest Division reveal the presence of eight tree species, four shrub species, and 12 herb species, including Hawthorn (*Crataegus songarica*). Among the tree species, *Cedrus deodara* exhibited the highest Importance Value Index (IVI) with a value of 72.37, followed by *Pinus walliachiana* (69.08), *Juglanas regia* (33.29), *Aesculus indica* (31.06), *Robinia pseudocacia* (26.80), *Celtris australis* (24.23), and *Morus nigra* (22.52). The lowest IVI was observed for *Morus alba* (20.64) (Table 31). Among the shrub species in the area, *Crataegus songarica* dominated with an IVI value of 67.58, followed by *Berberis lycium* (61.67), *Parrotia jacquemontiana* (61.00), and *Vibernum grandiflorum* (55.08). The lowest IVI was observed for *Indigofera heterantha* (54.67) (Table 32). Among the herb species, *Cynodon dactylon* exhibited the highest IVI (33.68), followed by *Taraxacum officinale* (29.41), *Mentha spicata* (27.00), and *Fritillaria imperialis* (26.05). The lowest IVI was observed for *Viola odorata* (19.93) (Table 33).

Numerous researchers have extensively investigated the floristic diversity of plant species across the globe. Aijaz *et al.,* (2022) conducted a study on the floristic diversity in the Overa wildlife sanctuary located in the Kashmir Valley of Jammu and Kashmir, Union Territory of India. They recorded a total of 37 plant species belonging to 25 families in the study area. Among these species, 8 were trees, 8 were shrubs, and 21 were herbs. The dominant family among the recorded families was Asteraceae, represented by 4 species, followed by Pinaceae and Fabaceae with 3 species each. The phytosociological analysis of different habitats revealed that *Abies pindrow* and *Pinus wallichiana* were the dominant tree species in woodland and riverine habitats, while *Abies pindrow* and *Picea smithiana* dominated the coniferous habitat. *Betula utilis* and *Picea smithiana* were the dominant species in the subalpine pasture habitat. In terms of shrubs, *Viburnum grandiflorum was* the most dominant species in woodland, riverine, and coniferous habitats, whereas *Juniperus communis* was dominant in the subalpine pasture habitat. Among herbs, *Fragaria vesca* dominated in woodland, riverine,

and coniferous habitats, while *Trifolium repens* was dominant in the subalpine pasture habitat. In a separate study, Shahid and Joshi (2016) investigated the forests of Doon Valley, Shivalik hills in the lower Himalayas. They reported *Shorea robusta* as the dominant species in the Barkot range, with an Importance Value Index (IVI) value of 141.32. The co-dominant species were *Mallotus philippensis* and *Ehretia laevis,* with IVI values of 33.53 and 31.68, respectively.

Pandey *et al*., (2016) conducted a study on the structure, composition, and diversity of forests along the altitudinal gradient in the Himalayas, Nepal. They found that Tsuga dumosa was the ecologically most important species in both the upper and lower subalpine zones, with a high Important Value Index (IVI) of 124.31. In the upper and lower temperate zones, *Quercus semecarpifolia* and *Lithocarpus elegans* were the ecologically most important species, with IVI values of 66.64 and 46.39, respectively. The Shannon diversity index ranged from 1.10 to 2.34, with the highest value observed in the lower temperate zone.

Furthermore, Wani and Pant (2023) studied the floristic diversity and community characteristics of the Gulmarg Wildlife Sanctuary. They reported a total of 364 species of vascular plants in the area, distributed among 74 families, including 22 trees, 34 shrubs, and 290 herbs. The tree density and total basal area ranged from 185 to 810 m^2 per hectare and 20.28 to 159.8 m^2 per hectare, respectively. In the forest zone, the density of shrubs ranged from 886 to 2040 m^2 per hectare, while the density of herbs ranged from 27.79 to 87.75 m^2 per hectare.

The Importance Value Index (IVI) is a crucial ecological metric used to assess the relative significance of plant species within a specific ecosystem. This study investigated the IVI of *Crataegus songarica* across various Forest Divisions in Kashmir Himalayas. The results indicate notable variations in IVI values among different divisions, shedding light on the distribution and ecological prominence of *Crataegus songarica* within the region's diverse forest ecosystems.

The highest IVI value for *Crataegus songarica* was recorded within the Langate Forest Division, reaching an impressive value of 85.07, which may be attributed to the relatively open nature of this division's habitat. This finding suggests that *Crataegus songarica* occupies a central role in the Langate forest ecosystem, potentially indicating its ecological importance in terms of habitat provision, nutrient cycling, and overall ecosystem stability. Following Langate, the Tangmarg Forest Division exhibited a considerably high IVI value of 72.74 for *Crataegus songarica*. This suggests that the species maintains a substantial presence within this division, albeit to a slightly lesser extent than in Langate Forest Division. Similarly, the Kehmil Forest Division demonstrated a comparable IVI value of 72.41, indicating a substantial occurrence of *Crataegus songarica* within this division's ecosystem.

As the IVI values decrease, the presence of *Crataegus songarica* within the ecosystem becomes relatively less pronounced. The Bandipora Forest Division reported an IVI value of 69.69, followed by the Baramulla Forest Division with a value of 67.58. The declining trend in IVI values across these divisions could be indicative of decreasing habitat suitability or other ecological factors that influence the species distribution. Continuing the pattern, the Sindh Forest Division exhibited an IVI value of 61.79, suggesting a moderate presence of *Crataegus songarica* within the division. Subsequent divisions displayed declining IVI values: Budgam Forest Division (55.53), Anantnag Forest Division (47.48) and Shopian Forest Division (46.47). These lower IVI values may be indicative of marginal habitat suitability or the prevalence of ecological factors less favorable to the species. Notably, the Kamraj Forest Division reported the lowest IVI value of 46.28 for *Crataegus songarica*, suggesting a minimal presence of the species within this division's ecosystem.

The assessment of vegetation density and Importance Value Index (IVI) in various forest divisions provides valuable insights into the ecological characteristics and health of these ecosystems. Total density of trees was

recorded highest for Kehmil Forest Division (1366.43 ha^{-1}) and lowest was recorded for Bandipora Forest Division (780.91 ha^{-1}). It was observed from the studies conducted that the lower density areas resulted in high IVI values of *Crataegus songarica* in the study area. This variation can be attributed to differences in environmental factors, land use and management practices. The higher tree density in Kehmil Forest Division may indicate a well-preserved and diverse forest ecosystem, potentially benefiting from effective conservation efforts. Conversely, the lower tree density in Bandipora Forest Division could signal the need for more robust conservation strategies to protect and enhance tree populations in this area.

Studies conducted also demonstrated substantial diversity in the total density of shrubs among the forest divisions. Sindh Forest Division exhibited the highest shrub density at 2550.98 ha^{-1}, while Langate Forest Division had the lowest shrub density at 917.6 ha^{-1}. These differences may arise from variations in soil types, climate and human activities such as grazing and land clearance. Sindh Forest Division's high shrub density suggests the presence of a dense understorey. On the other hand, the lower shrub density in Langate Forest Division could indicate a need for targeted restoration efforts to bolster shrub populations and enhance ecological functions in this area.

The study also assessed the total density of herbs across different forest divisions. Anantnag Forest Division recorded the highest herb density at 82.18 m^2, while Bandipora Forest Division exhibited the lowest herb density at 59.31 m^2. The higher herb density in Anantnag Forest Division suggests favorable conditions for herbaceous plant growth, which may contribute to greater biodiversity and forage availability for herbivores. Conversely, Bandipora Forest Division's lower herb density may warrant attention to improve conditions for herbaceous vegetation, potentially enhancing overall ecosystem health.

One particularly interesting observation from our study was the association between lower density areas and higher IVI values for *Crataegus songarica*. This indicates that in areas where *Crataegus songarica* is less common, it plays a more significant role in the overall forest composition. This finding underscores the ecological importance of this species in the study area, highlighting its potential value for conservation efforts and ecosystem management. The association between lower density areas and higher IVI values for *Crataegus songarica* highlights the need for targeted conservation efforts to protect and promote the ecological significance of this species. Future research and management strategies should take into account these findings to better preserve and sustainably manage the diverse forest ecosystems in the study area.

The diversity index values of trees in this study ranged from 1.69 to 3.21, which is consistent with the values reported by previous studies. Ghildiyal *et al*., (1998) reported values ranging from 1.86 to 2.73, Uniyal *et al*., (2010) reported values ranging from 0.70 to 3.08, Raturi (2012) reported values ranging from 0.78 to 3.45, Pant and Sammant (2012) reported values ranging from 0.74 to 2.66, Singh *et al*., (2014) reported values ranging from 0.66 to 2.69, and Verma (2016) reported values ranging from 1.1 to 2.05. Regarding shrubs, the diversity index values ranged from 1.03 to 1.73, which falls within the range reported by Gairola *et al*., (2008) in the sub-alpine zone of the Western Himalaya, India (1.05-2.57), and Verma (2016) in District Chamba, Himachal Pradesh (1.7-2.5). In terms of herbs, the diversity index values in our study ranged from 2.46 to 3.97, which aligns with the range of values reported by previous studies. Gairola *et al*., (2008) reported values ranging from 2.40 to 3.35 in the sub-alpine zone of the Western Himalaya, India, Bharali *et al*., (2011) reported values ranging from 2.49 to 3.01 in the west siang district of Arunachal Pradesh, India, and Verma (2016) reported values ranging from 3.16 to 3.20 in District Chamba, Himachal Pradesh.

5.2 To study propagation of *Crataegus songarica* through cuttings and seeds

5.2.1 Morphometric characteristics of *Crataegus songarica*

Studies were conducted to investigate the morphometric characteristics of *Crataegus songarica*. Valuable insights were gained through the conducted studies, which focused on various morphometric parameters of Hawthorn seeds. The results revealed that Hawthorn exhibited a wide range of seed weights, with a maximum of 13.48 g per 100 seeds, a minimum of 9.67 g, and an average of 11.49 g per 100 seeds. Regarding seed diameter, Hawthorn displayed a range from 4.39 mm to 6.64 mm, with an average diameter of 5.65 mm. The seed length varied between 7.26 mm and 8.21 mm, with an average length of 7.67 mm. Additionally, Hawthorn's seed moisture content ranged from 7.96% to 9.31%, with an average moisture content of 8.46%.

In comparison to previous research, Kheloufi *et al*., (2019) reported different measurements for *Crataegus monogyna*, with a seed length of 8.9±0.43 mm, a seed diameter of 6.75±0.39 mm, and a weight of 0.25±0.04 g. They also reported a thousand seed weight of 2000 g. Another study conducted by Gokturk *et al*., (2017) highlighted significant variations in seed diameter, length, moisture content, and seed weight among different Crataegus species. For instance, *Crataegus orientalis* had the smallest seed length of 6.37 mm and a seed diameter of 3.48 mm. On the other hand, *Crataegus pseudoheterophylla* exhibited the largest seed length of 8.38 mm and a seed diameter of 6.56 mm. Moreover, *Crataegus orientalis* had the smallest seed weight of 8.88 g and the highest moisture content of 8.98%, while *Crataegus monogyna* reported a moisture content of 8.57%.

These findings contribute to the understanding of the morphometric characteristics of *Crataegus songarica* in Kashmir Himalayas and provide a comparative analysis with other Crataegus species.

5.2.2 Propagation of *Crataegus songarica* through seeds

Seed experiments were carried out to investigate the effect of scarification using sulfuric acid and cold stratification on the germination and growth characteristics of Hawthorn, *Crataegus songarica*, in the Kashmir Himalayas. Prior to planting, the seeds underwent treatment with concentrated sulfuric acid for one hour, followed by cold stratification for various durations (40, 50, 60, and 70 days), in addition to mechanical scarification using a hammer. The effects of these seed treatments were then assessed based on parameters such as germination percentage, germination energy, germination value, shoot length (cm), root length (cm), average number of roots, vigor index, and leaf area (cm^2).

Germination percentage

The present study aimed to investigate the effect of scarification and stratification treatments on the germination percentage of Hawthorn (*Crataegus songarica*). The results indicated that scarification, particularly with concentrated sulfuric acid, along with cold stratification, significantly influenced the germination percentage of the seeds. Among the treatment groups, the highest germination percentage of 36.66% was achieved in T5, where seeds underwent scarification with concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. This treatment proved to be the most effective in breaking seed dormancy and promoting germination. Similarly, T4, which involved scarification with concentrated sulfuric acid (50%) followed by a cold stratification period of 60 days, and T3, employing a cold stratification period of 50 days, resulted in considerable germination percentages of 33.33% and 31.66%, respectively. These findings demonstrate the positive influence of both scarification and stratification on seed germination. The germination percentage declined when the cold stratification period was reduced. T2, which utilized scarification with concentrated sulfuric acid (50%) and a cold stratification period of 40 days, yielded a germination percentage of 26.66%. This suggests that a longer stratification period allows for improved seed dormancy breaking and subsequently higher germination rates.

Interestingly, mechanical scarification using a hammer (T6) resulted in a germination percentage of 25.00%. Although this treatment was less effective than sulfuric acid scarification combined with stratification, it still demonstrated a positive impact on germination when compared to the control group. Comparatively, the control group exhibited the lowest germination percentage of 10.00%.

Several researchers have previously reported improvements in seed germination through scarification and cold stratification treatments. For instance, Holmes and Buszewicz (1958) demonstrated enhanced germination in *Crataegus monogyna* by treating seeds with sulfuric acid for 1 to 2 hours, followed by cold stratification. Borkowsa (2007) found that cold stratification and warm stratification were effective methods for breaking dormancy in *Craetaegus pedicellata* at temperatures of 25°C or 30°C, with specific light and dark cycles, followed by a cold stage at 3°C. The author also reported that chemical stratification using 96% sulfuric acid for 2 hours, followed by warm and cold stratification with a short warm stage, resulted in a high emergence rate (85-93%). Furthermore, Borkowsa (2006) reported that stratified seeds of *Crataegus laevigata* exhibited vigorous germination within 3-5 weeks at temperatures ranging from 15º to 20°C, with specific light and dark cycles, and all seedlings emerged within 4-6 weeks after sowing. Aslam, (2018) reported that germination percentage of *Betula utilis* seeds under different cold stratification durations increased upto seventy five days and there after decreased. Additionally, Qrunfleh (1991) reported that cold stratification improved seed germination in *Craetaegus azarollus* L.

The findings of this study, along with previous research, highlight the effectiveness of scarification with sulfuric acid and cold stratification treatments in enhancing the germination percentage of Hawthorn (*Crataegus songarica*) seeds. These methods offer potential applications for improving germination rates in related species as well.

Germination energy (%)

The results demonstrated that scarification with concentrated sulfuric acid significantly improved the germination energy of Hawthorn seeds when compared to the control group (T0). T1, which underwent scarification with concentrated sulfuric acid for 50 days, exhibited a germination energy of 16.66%, indicating the positive impact of this treatment. As the duration of cold stratification increased, the germination energy also improved. T2, which involved scarification with concentrated sulfuric acid for 40 days followed by cold stratification for 40 days, resulted in a germination energy of 23.33%. Subsequent treatment combinations, T3, T4 and T5, yielded even higher germination energies of 28.33%, 30.00%, and 31.66%, respectively. T5, which involved scarification with concentrated sulfuric acid for 50 days followed by cold stratification for 70 days, displayed the highest germination energy among all treatments. Mechanical scarification using a hammer (T6) resulted in a germination energy of 21.66%, suggesting that this method can also be effective, although less so than scarification with sulfuric acid.

Based on the data presented in the table 36, it is evident that scarification with sulfuric acid, combined with cold stratification ranging from 40 to 70 days, effectively increased the germination energy in Hawthorn, *Crataegus songarica*. Scarification weakens the hard seed coat, enabling improved water absorption and embryo emergence, while cold stratification simulates the necessary chilling requirement for germination and breaks seed dormancy. The combined effects of these treatments resulted in higher germination energy, indicating successful alleviation of dormancy in the seeds. These findings align with previous studies conducted by Kheloufi *et al*., (2019), Gokturk *et al*., (2017), and Borkowsa (2007), further supporting the effectiveness of scarification and stratification techniques in improving germination rates and energy in various plant species, including Hawthorn (*Crataegus songarica*).

Germination value

The conducted studies revealed that the germination value of Hawthorn, *Crataegus songarica*, was significantly influenced by different scarification and stratification treatments. The results demonstrated varying effects of the treatment combinations on the germination value. Among these combinations, the highest germination value of 4.21 was observed in T5, which involved scarification with concentrated sulfuric acid (50%) followed by 70 days of cold stratification. T5 was statistically at par with T4 (germination value of 3.87), which utilized scarification with concentrated sulfuric acid (50%) and 60 days of cold stratification, and T3 (germination value of 4.07), employing scarification with concentrated sulfuric acid (50%) and 50 days of cold stratification.

T2 resulted in a germination value of 2.06, involving scarification using concentrated sulfuric acid (50%) and 40 days of cold stratification. Mechanical scarification with a hammer (T6) yielded a germination value of 1.75, while T1, which employed scarification with concentrated sulfuric acid (50%), showed a germination value of 1.23. Importantly, the control group (T0) exhibited the lowest germination value of 0.62.

The observed improvements in germination value can be attributed to the mechanisms associated with scarification and cold stratification. Scarification with concentrated sulfuric acid softens or removes the tough seed coat, enabling water uptake and initiating the germination process. This treatment also promotes gas exchange, nutrient uptake, and hormonal changes that facilitate germination. Cold stratification mimics the natural winter conditions required for Hawthorn seed dormancy breakage. It facilitates the degradation of growth inhibitors and stimulates hormonal changes necessary for seed germination. Furthermore, the combination of scarification and cold stratification likely exhibits a synergistic effect on hawthorn seed germination. Scarification allows water and germination-promoting substances to penetrate the seed, while cold stratification triggers

physiological changes that prepare the embryo for growth. The sequential application of these treatments addresses multiple factors contributing to seed dormancy, resulting in an overall enhanced germination value (Gokturk *et al*., 2017, Borkowsa, 2006).

Length of root (cm)

The conducted studies revealed a notable influence of scarification and stratification treatments on root development in Hawthorn, scientifically known as *Crataegus songarica*. The results demonstrated varying root lengths under different treatment conditions. The treatment labeled as T3, where the seeds underwent scarification using concentrated sulfuric acid (50%) followed by cold stratification for 50 days, exhibited the highest root length of 5.69 cm. This was followed by T5, which involved involved scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days, resulting in a root length of 4.77 cm, while T4, with scarification and cold stratification for 60 days, showed a root length of 4.66 cm. On the other hand, T6, which used mechanical scarification with a hammer, resulted in a root length of 3.53 cm. T2, with scarification using concentrated sulfuric acid (50%) and cold stratification for 40 days, displayed a root length of 3.47 cm. Meanwhile, T1, where scarification was solely performed with concentrated sulfuric acid (50%), showed a root length of 3.20 cm. The control group (T0) recorded the lowest root length of 1.55 cm.

Scarification, known for breaking seed coat dormancy and enhancing water and oxygen absorption, likely facilitated water uptake through mechanical abrasion, thereby accelerating seedling establishment. This hypothesis finds support in the rapid increase in root length observed in the scarification group, suggesting that scarified seeds absorbed moisture more efficiently, leading to improved root development.

On the other hand, stratification treatment mimics the natural winter conditions necessary for germination in certain plant species. Cold and moist

stratification likely induced hormonal changes in the hawthorn seeds, breaking dormancy and stimulating root growth. Prolonged exposure to low temperatures and moisture may have provided the required signals for seedlings to initiate root development more vigorously. This accounts for the significant increase in root length observed in the stratification group (Borkowsa 2006, Borkowsa, 2007, Gokturk *et al*., 2017).

It is important to note that the effects of scarification and stratification on root length may be influenced by various factors, including seed age, species-specific characteristics, and environmental conditions. Furthermore, future studies should explore the potential synergistic effects resulting from the combined use of scarification and stratification

Average number of roots

The conducted studies revealed a significant impact of scarification and stratification treatments on the average number of roots in Hawthorn, *Crataegus songarica*. The results showed noteworthy variations among the different treatment groups. Among the treatments, T3 showed the highest average number of roots at 9.66, which involved scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days. T3 was statistically at par with T4, which utilized scarification with concentrated sulfuric acid (50%) and cold stratification for 60 days, resulting in an average of 9.00 roots, and T5, where scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days yielded an average of 8.66 roots. On the other hand, T2, which included scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, had an average of 8.33 roots, while T1, involving scarification with concentrated sulfuric acid (50%), yielded an average of 7.69 roots. Lastly, T6, which employed mechanical scarification with a hammer, resulted in an average of 7.00 roots. The control group (T0) exhibited the lowest average number of

roots at 4.66.These findings highlight the influence of scarification and stratification treatments on root development in Hawthorn, *Crataegus songarica*.

Several factors can be attributed to the observed improvement in root development. Scarification breaks down the hard seed coat, enhancing water and oxygen uptake and facilitating the penetration of root-promoting substances. Stratification, by simulating winter conditions, helps overcome seed dormancy and triggers hormonal changes that stimulate root growth. The combined effect of scarification and stratification likely enhances these processes, leading to the development of a more robust root system (Borkowsa, 2006, Borkowsa, 2007, Gokturk *et al*., 2017).

Seedling height (cm)

The conducted studies revealed that scarification and stratification treatments have a significant impact on the height of Hawthorn seedlings, *Crataegus songarica*. The treatment that resulted in the tallest seedlings was T5, where scarification with concentrated sulfuric acid (50%) and cold stratification for 70 days were employed, leading to a recorded height of 14.37 cm. This was followed by T4, which involved scarification with concentrated sulfuric acid (50%) and cold stratification for 60 days, and T3, which resulted in a seedling height of 12.00 cm through scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days. On the other hand, seedlings in treatment T6, which utilized mechanical scarification with a hammer, reached a height of 11.47 cm. Treatment T2, comprising scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, resulted in seedlings with a height of 9.41 cm. The shortest seedlings, with a height of 8.50 cm, were observed in treatment T1, which involved scarification with concentrated sulfuric acid (50%) alone. The control group (T0) exhibited the lowest seedling height of 5.64 cm.

The improvement in seedling height can be attributed to the successful emergence of seedlings facilitated by scarification, as well as the subsequent

favorable physiological changes induced by stratification. Scarification allowed for rapid and uniform germination, while stratification initiated early growth and provided a competitive advantage for the developing seedlings. The increased seedling height observed in the group combining scarification with stratification can be attributed to the cumulative effects of both treatments, effectively facilitating the seedling's initial growth phase (Borkowsa, 2006, Borkowsa, 2007, Gokturk *et al*., 2017).

.**Vigour index**

The conducted studies have shown that the application of scarification and stratification treatments significantly affects the vigor index of Hawthorn (*Crataegus songarica*). Among the various treatments, the highest vigor index of 526.26 was observed in treatment T5. This treatment involved scarification using concentrated sulfuric acid (50%) followed by cold stratification for 70 days. This was followed by T4, which achieved a vigor index of 404.10 through scarification using concentrated sulfuric acid (50%) and cold stratification for 60 days, as well as T3, which utilized scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days, resulting in a vigor index of 379.58. Mechanical scarification using a hammer in treatment T6 resulted in a vigor index of 287.78, whereas treatment T2, involving scarification with concentrated sulfuric acid (50%) and cold stratification for 40 days, produced a vigor index of 250.18. The control group recorded the lowest vigor index of 56.40.

The observed enhancements in the vigor index as a result of scarification and stratification treatments can be attributed to several factors. Scarification likely assists in overcoming physical seed coat barriers, facilitating water and gas exchange, thereby promoting germination. The increased germination percentage observed in scarified seeds suggests that scarification is an effective method for enhancing hawthorn seedling establishment.

On the other hand, stratification primarily breaks seed dormancy and synchronizes germination, leading to higher germination rates. The cold and moist conditions provided during stratification likely initiate biochemical changes in the seeds, preparing them for subsequent growth. The improved vigor index in stratified seeds suggests that this pre-germination treatment is crucial for maximizing hawthorn seedling performance.

The findings of this study have practical implications for hawthorn cultivation and ecological restoration efforts. Incorporating scarification as a standard pre-germination treatment can enhance germination rates and improve seedling establishment. Similarly, implementing stratification protocols that mimic natural winter conditions can promote consistent germination and increase the overall vigor of Hawthorn seedlings (Borkowsa, 2006, Borkowsa, 2007, Gokturk *et al*., 2017).

.**Leaf area (cm^2)**

The conducted studies have provided valuable insights into the effects of scarification and stratification treatments on the leaf area of Hawthorn, *Crataegus songarica*. The treatment that produced the highest leaf area, measuring 27.71 cm^2, was T5. This treatment involved scarification using concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. This was followed by T4, which yielded a leaf area of 25.37 cm^2 by employing scarification with concentrated sulfuric acid (50%) and a cold stratification period of 60 days and T6, utilizing mechanical scarification with a hammer, exhibited a leaf area of 25.53 cm^2. The control treatment, T0, recorded the lowest leaf area of 23.21 cm^2.

These findings contribute valuable insights into the influence of scarification and stratification on leaf area in Hawthorn. The increase in leaf area observed in scarified seeds suggests that seed coat dormancy and impermeability can restrict germination and subsequent leaf development. Scarification effectively overcomes these barriers, promoting faster and more robust seedling

establishment. The improved leaf area resulting from scarification carries important implications for horticultural practices, including nursery production and ecological restoration efforts involving hawthorn. The cold stratification process likely induced physiological changes in the seeds, breaking their dormancy and preparing them for growth. The observed increase in leaf area suggests that stratification can enhance seedling vigor and establish a more favorable foundation for subsequent growth stages. Overall, the findings of this study contribute to our understanding of seed treatments in Hawthorn and provide practical applications for improving leaf area and overall plant performance. The results underscore the importance of scarification and stratification as valuable techniques for promoting successful seed germination and seedling establishment in Hawthorn cultivation and ecological restoration efforts.

5.2.2 To study propagation of *Crataegus songarica* through cuttings

Sprouting percentage

Studies conducted indicated that the sprouting percentage was significantly affected by different concentrations of IBA and NAA. When cuttings were treated with IBA at 4000 ppm (T4), the highest sprouting percentage of 93.33% was observed. Additionally, T4 (IBA 4000 ppm) followed by IBA at 5000 ppm (86.66%), IBA at 2000 ppm and NAA at 4000 ppm (both 85.00%), IBA at 6000 ppm and NAA at 3000 ppm (both 83.33%), and IBA at 1000 ppm and NAA at 5000 ppm (both 81.66%). The sprouting percentages declined further with NAA at 2000 ppm (78.77%) and NAA at 1000 ppm (76.77%). The control group (T0), where cuttings were treated with distilled water, exhibited the lowest sprouting percentage of 75.00% .

The improved sprouting percentage observed in hawthorn cuttings treated with IBA and NAA confirms the positive effects of these synthetic auxins on root development and shoot initiation. IBA and NAA are known to stimulate cell division, elongation, and differentiation, leading to enhanced adventitious root

formation and overall cutting vigor. The higher sprouting percentage in IBA-treated cuttings can be attributed to its ability to promote root development, providing a strong foundation for subsequent shoot growth. Conversely, NAA's influence on shoot development may have resulted in increased shoot production, although with a slightly lower percentage of root formation.

These findings suggest that the selection of auxin treatment should be tailored to the specific goals of propagation. If the objective is to establish a high root-to-shoot ratio and ensure strong root formation, IBA treatment may be preferred. However, it is worth noting that the decrease in sprouting percentage observed with an increased IBA concentration of 6000 ppm indicates that hawthorn cuttings may be sensitive to higher concentrations of IBA, leading to inhibitory effects on root initiation and development.

Previous studies by various researchers have also reported the effects of growth hormones on sprouting percentage. Pain and Roy (1981), in their study on *Dalbergia sissoo*, reported significant improvements in sprouting due to the application of IBA and other chemicals. Nanda *et al*., (1975) found that the application of auxin resulted in the breakdown of starch into soluble sugars, with a substantial portion being utilized for the growth of new sprouts. The reduction in sprouting at higher IBA concentrations may be attributed to supraoptimal levels. Nazir *et al*., (2021) reported maximum sprouting at IBA concentration of 2500 ppm for Elm species in Kashmir. Rafeeq *et al*., (2020) also observed significant increase in sprouting in *Morus alba* due to IBA treatments

Rooting percentage

Regarding the rooting percentage, studies conducted showed a significant effect of various concentrations of IBA and NAA. The highest rooting percentage of 76.66% was observed in cuttings treated with IBA at 4000 ppm (T4). T4 was followed by IBA at 5000 ppm (73.33%) and IBA at 6000 ppm (70.00%). The rooting percentage declined for T3 (IBA 3000 ppm) with a value of 68.33%, IBA

at 2000 ppm (65.00%), NAA at 4000 ppm (61.66%) and NAA at 3000 ppm (58.33%). Cuttings treated with IBA at 1000 ppm (T1) showed a rooting percentage of 56.66%, which was similar to NAA at 5000 ppm (56.00%), NAA at 6000 ppm (55.00%), NAA at 2000 ppm (53.33%) and NAA at 1000 ppm (50.00%). The control group (T0) with cuttings treated with distilled water exhibited the lowest rooting percentage of 26.66%.

The findings of this study confirm the effectiveness of IBA and NAA in enhancing the rooting percentage of hawthorn cuttings compared to the control group. The observed increase in rooting percentage can be attributed to the auxin-like properties of IBA and NAA, which stimulate cell division and elongation, leading to adventitious root formation. The optimal concentration of IBA (4000 ppm) determined in this study can serve as practical guidelines for hawthorn propagation protocols. The improved rooting percentage achieved through the application of IBA and NAA has significant implications for hawthorn production, as it allows for efficient and reliable propagation of desirable hawthorn cultivars. However, the decrease in rooting percentage observed at the higher IBA concentration of 6000 ppm suggests that Hawthorn cuttings may be sensitive to elevated IBA concentrations, resulting in inhibitory effects on root initiation and development.

Previous studies by Nazir *et al*., (2021) reported a maximum rooting percentage of 90.88% for Elm species in Kashmir with IBA at 2500 ppm. Rafeeq *et al*., (2020) observed a significant increase in rooting for Morus alba due to IBA treatments. Choudhary and Singh (2021) reported that IBA at 4000 ppm significantly improved rooting up to 82.83% in *Punica granatum*, with a decreasing trend observed at concentrations above 4000 ppm. Ma *et al*., (2022) reported improved rooting in Fig cuttings when treated with IBA and NAA. The highest percentage of rooting (78.7%) was recorded three months after planting when cuttings were treated with IBA at 4000 ppm.

Average number of roots per cutting

Studies conducted revealed a significant variation in the number of roots observed in cuttings depending on the application of IBA and NAA. The treatments had a notable impact on the average number of roots per cutting. Particularly, cuttings treated with an IBA concentration of 4000 ppm (T4) exhibited the highest average number of roots, reaching 17.33. T4 (IBA 4000 ppm) showed statistically similar results to 3000 ppm of IBA, recording an average of 16.66 roots, whereas 5000 ppm of IBA had an average of 14.33 roots and 400 ppm of NAA showed an average of 14.00 roots. The trend continued with decreasing average numbers of roots for the cuttings treated with 2000 ppm of IBA (T2), which recorded 13.22 average roots. T2 was statistically comparable to 3000 ppm of NAA (12.93), 6000 ppm of IBA (12.33), and 2000 ppm of NAA (11.00). T9 (5000 ppm of NAA) showed an average number of roots of 8.66, and it was statistically at par with 1000 ppm of IBA (8.33) and 6000 ppm of NAA (7.63). The control group, cuttings treated with distilled water, exhibited the lowest average number of roots, amounting to 5.66.

The findings of this study provide compelling evidence that IBA and NAA effectively enhance the average number of roots in hawthorn cuttings. This positive impact can be attributed to the auxin-like properties of IBA and NAA, which promote cell division and elongation, ultimately leading to the formation of adventitious roots. The synergistic effects observed with the application of IBA and NAA suggest their complementary roles in stimulating root development. The determined optimal concentration of IBA (4000 ppm) can serve as practical guidelines for hawthorn propagation protocols aimed at increasing the average number of roots. The enhanced root development achieved through the application of IBA and NAA holds significant implications for hawthorn production. However, the decrease in the average number of roots observed with the increased IBA concentration of 6000 ppm suggests that hawthorn cuttings

might be sensitive to higher concentrations of IBA, leading to inhibitory effects on root initiation and development.

Similar observations have been made in other studies. Pain and Roy (1981) and Shamat and Kumar (1988) noted a differential increase in the number of roots per cutting in *Dalbergia sisoo* due to IBA, IAA, and NAA. Rafeeq *et al*., (2020) reported a significant increase in the average number of roots in Morus alba as a result of IBA treatments. Chaudhary and Singh (2021) reported that in *Punica granatum*, cuttings treated with 4000 ppm of IBA showed the highest number of primary roots (44.37), followed by 42.42 when treated with 5000 ppm of IBA.

Average root length (cm)

Regarding the average root length (cm), studies conducted indicates that different concentrations of IBA and NAA significantly affected it. Cuttings treated with IBA at a concentration of 4000 ppm (T4) displayed the longest average root length of 11.03 cm. T4 (IBA 4000 ppm) was followed by IBA at 3000 ppm (8.93 cm), IBA at 2000 ppm (8.43 cm), and IBA at 1000 ppm (7.96 cm). Cuttings treated with IBA at 5000 ppm (T5) showed an average root length of 6.56 cm. T5 was statistically comparable to NAA at 4000 ppm (6.43 cm), NAA at 3000 ppm (6.26 cm), and NAA at 2000 ppm (6.00 cm). Cuttings treated with IBA at 6000 ppm (T6) had an average root length of 5.93 cm. T6 was statistically at par with NAA at 1000 ppm (5.87 cm), NAA at 5000 ppm (5.80 cm) and NAA at 6000 ppm (5.53 cm). The control group (T0), treated with distilled water, exhibited the shortest average root length of 3.63 cm.

These findings provide compelling evidence that IBA and NAA effectively enhance the average root length of Hawthorn cuttings. This positive influence can be attributed to the auxin-like properties of IBA and NAA, which stimulate cell elongation and differentiation, leading to increased root development. The identified optimal concentration of IBA (4000 ppm) can serve

as a practical guideline for hawthorn propagation protocols, aimed at achieving longer average root length. However, the decrease in average root length observed with an increased IBA concentration of 6000 ppm indicates that hawthorn cuttings may be sensitive to higher IBA concentrations, resulting in inhibitory effects on root initiation and development.

Similar trends have been observed in other plant species. Nazir *et al*., (2021) observed the maximum root length in *Ulmus walliachiana* at an IBA concentration of 2000 ppm. Rafeeq *et al*., (2020) reported a significant increase in root length in *Morus alba* due to IBA treatments. In the case of *Punica granatum*, Chaudhary and Singh (2021) reported the highest root length of 16.37 cm in cuttings treated with IBA at 4000 ppm, followed by 15.64 cm when treated with IBA at 5000 ppm.

Collar diameter of leading shoot (mm)

Regarding collar diameter of the leading shoot, treatments also had a significant effect. Cuttings treated with 4000 ppm IBA (T4) exhibited the highest collar diameter of 7.03 mm, followed by cuttings treated with 3000 ppm IBA (T3) with a collar diameter of 6.22 mm, 2000 ppm IBA (5.93 mm) and 1000 ppm IBA (5.67 mm). Furthermore, cuttings treated with 4000 ppm NAA (T10) had a collar diameter of 5.24 mm followed by 5000 ppm IBA (4.97 mm), 3000 ppm NAA (4.89 mm), 2000 ppm NAA (4.78 mm), and 5000 ppm NAA (4.61 mm). Cuttings treated with 6000 ppm IBA (T6) had a collar diameter of 4.55 mm, which was statistically similar to those treated with 1000 ppm NAA (4.37 mm) and 6000 ppm NAA (4.25 mm). The control group recorded the lowest collar diameter of 3.82 mm.

The findings of this study revealed significant differences in the collar diameter of the leading shoots among the treatment groups. Specifically, hawthorn plants treated with IBA showed a substantial increase in collar diameter compared to the control group. These results provide valuable insights into the effects of

IBA and NAA on the collar diameter of leading shoots in hawthorn cultivation. The significant increase in collar diameter observed in the IBA-treated plants suggests the potential of IBA as a growth-promoting agent in hawthorn cultivation. This could be attributed to the promotion of cell division and elongation by IBA, which likely contributed to enhanced shoot growth. Conversely, the NAA-treated plants exhibited a slight reduction in collar diameter, indicating the potential of NAA as a growth regulator, possibly by inhibiting excessive shoot elongation.

Supporting studies by Rafeeq *et al*., (2020) on *Morus alba* and Khandaker *et al*., (2022) on *Syzygium samarangense* reported similar trends in collar diameter increase when treated with IBA, further supporting the findings of this study.

Leaf area (cm^2)

The data presented in the table 39 shows the effect of different concentrations of IBA and NAA on total leaf area. Cuttings treated with IBA at a concentration of 4000 ppm (T4) showed the highest leaf area of 28.68 cm^2, which was statistically at par with IBA at 3000 ppm (28.17 cm^2). Cuttings treated with IBA at 5000 ppm (T5) showed total leaf area of 26.71 cm^2, which was statistically at par with with IBA at 2000 ppm (26.46 cm^2). Cuttings treated with NAA at 4000 ppm showed total leaf area of 26.03 cm^2, which was statistically at par with IBA at 1000 ppm (25.93 cm^2), IBA at 6000 ppm (25.58 cm^2) and NAA at 3000 ppm (25.21 cm^2). Cuttings treated with NAA at 2000 ppm showed total leaf area of 25.24 cm^2, which was statistically at par with NAA at 1000 ppm (24.28 cm^2), NAA at 5000 ppm (25.13 cm^2) and NAA 6000 ppm (24.24 cm^2). The lowest total leaf area (24.12 cm^2) was recorded in control (T0).

The observed increase in leaf area can be attributed to the physiological and biochemical changes induced by IBA and NAA. These growth regulators have the ability to influence cell division, elongation, and differentiation,

consequently affecting leaf development. The promotion of cell division and expansion by IBA and NAA may have contributed to the observed increase in leaf area among the treated plants. Moreover, the application of IBA and NAA might have influenced the hormonal balance within the plants, leading to an enlargement of leaf size. Auxins are known to interact with other plant hormones such as cytokinins, gibberellins, and abscisic acid, which are crucial regulators of leaf development. The interplay between these hormones could have been altered by the application of IBA and NAA, resulting in a positive effect on the expansion of leaf area.

On the other hand, the decrease in leaf area with an increase in IBA concentration suggests that higher levels of IBA may have an inhibitory effect on leaf growth in hawthorn plants. It is possible that elevated IBA concentrations disrupt the balance of auxin signaling within the plant, leading to altered leaf development and reduced expansion.

The findings of this study are consistent with previous research. Nazir *et al*., (2021) reported that the maximum leaf area per sprouted stem cutting was observed at an IBA concentration of 2000 ppm. Similarly, Khandaker *et al*., (2022) found that *Syzygium samarangense* treated with IBA concentrations ranging from 1000 to 2000 ppm exhibited an increasing trend in leaf area.

Plant height (cm)

Regarding plant height (cm), studies conducted revealed that the average plant height was significantly affected by the treatments with IBA and NAA. Cuttings treated with 4000 ppm IBA demonstrated the maximum plant height of 27.53 cm, which was significantly different from the plant height observed in the other treatments. Cuttings treated with 3000 ppm IBA had a plant height of 24.66 cm. Cuttings treated with 2000 ppm IBA (T2) had a plant height of 21.83 cm, 5000 ppm IBA (20.43 cm), 4000 ppm NAA (19.06 cm) and 1000 ppm IBA (19.00 cm). Cuttings treated with 6000 ppm IBA had a plant height of 18.40 cm, which

was statistically similar to the plant height resulting from 3000 ppm NAA (18.26 cm) and 2000 ppm NAA (17.90 cm). Cuttings treated with 1000 ppm NAA had a plant height of 16.83 cm, which was statistically similar to the plant height resulting from 5000 ppm NAA (15.40 cm) and 6000 ppm NAA (14.53 cm). The control group (T0) displayed the lowest plant height of 13.10 cm, maintained by treating cuttings with distilled water.

These results demonstrate the significant positive effect of IBA and NAA application on the growth of hawthorn plants, specifically in terms of plant height. The findings align with the hypothesis that the use of these growth regulators can enhance the growth performance of hawthorn. However, the observed decrease in plant height with increasing IBA concentration raises several factors that could potentially explain this phenomenon.

One possible explanation is that higher concentrations of IBA may excessively stimulate root growth at the expense of shoot development. This imbalance in hormonal response could hinder shoot elongation and subsequently result in decreased plant height. Another possibility is that the high IBA concentration induces physiological stress on hawthorn plants, leading to growth inhibition. Excessive hormone application can disrupt the delicate hormonal balance within plants, thereby disrupting normal physiological processes and impeding growth.

In a study conducted by Nazir *et al*., in 2021 on Elm species, similar findings were observed regarding plant height. Maximum plant height was observed in T5, where a concentration of 2500 ppm IBA was used. These results provide further support for the positive impact of IBA on plant height in different plant species.

5.3 Chemical profiling of *Crataegus songarica*

This study aimed to examine the total phenol content, flavonoid content, and antioxidant activity in the fruits and leaves of Hawthorn (*Crataegus*

songarica) in the Kashmir Himalayas. Various fruit and leaf samples were collected from five different sites across the region, namely Site 1 (Malhar Ganderbal), Site 2 (Babareshi Gulmarg), Site 3 (Dachigam National Park), Site 4 (Ajas Bandipora), and Site 5 (Shikergah Tral). The collected samples were then evaluated for their total phenol content, flavonoid content, and antioxidant activity in both fruits and leaves.

In case of fruits, the conducted studies revealed that Malhar Ganderbal, identified as site 1, had the highest phenol content recorded at 38.28 mg GAE/g DW. Site 5, known as Shikergah Tral, had a total phenol content of 34.10 mg GAE/g DW, which was statistically comparable to site 2, named Babareshi Gulmarg, and site 4, referred to as Ajas Bandipora, with total phenol contents of 34.09 mg GAE/g DW and 33.68 mg GAE/g DW, respectively. The lowest total phenol content of 33.39 mg GAE/g DW was observed at site 3, known as Dachigam National Park. Regarding total flavonoids, the highest amount (5.71 mg QUE/g DW) was found in samples collected from site 2 (Babareshi Gulmarg) followed by site 1 (Malhar Ganderbal) with a total flavonoid content of 4.82 mg QUE/g DW, and site 3 (Dachigam National Park) with a total flavonoid content of 4.53 mg QUE/g DW. Site 5 (Shikergah Tral) recorded a total flavonoid content of 3.62 mg QUE/g DW, while the lowest content of 3.51 mg QUE/g DW was observed in samples collected from site 4 (Ajas Bandipora). In terms of antioxidant activity, the highest value of 1.71 mmol Fe++/g DW was recorded at site 1 (Malhar Ganderbal). Following this, site 2 (Babareshi Gulmarg) had an antioxidant activity of 1.20 mmol Fe++/g DW followed by site 3 (Dachigam National Park) with an antioxidant activity of 0.92 mmol Fe++/g DW, and site 5 (Shikergah Tral) with an antioxidant activity of 0.69 mmol Fe++/g DW. The lowest antioxidant activity (0.64 mmol Fe++/g DW) was found in samples collected from site 4 (Ajas Bandipora). Furthermore, the mean TSS (Total Soluble Solids) content observed in fruits was 14.07 Brix. Site 1 (Malhar Ganderbal) had

the maximum TSS content recorded at 16.50 Brix, while the minimum was observed in site 4 (Ajas Bandipora), with a TSS content of 12.40 Brix.

The research conducted on leaves revealed significant variations in phenol content, flavonoid content, and antioxidant activity across different sites. The studies conducted indicated that the total phenol content varied significantly among different sites. Malhar Ganderbal (Site 1) recorded the highest phenol content at 28.28 mg GAE/g DW. Babareshi Gulmarg (Site 2) had a total phenol content of 27.27 mg GAE/g DW, whereas Dachigam National Park (Site 3) at 26.48 mg GAE/g DW and Ajas Bandipora (Site 4) at 26.25 mg GAE/g DW. The lowest total phenol content of 25.70 mg GAE/g DW was found in samples collected from Shikergah Tral (Site 5).

Regarding total flavonoid content, the maximum value of 7.87 mg QUE/g DW was observed in samples from Babareshi Gulmarg (Site) followed by Malhar Ganderbal (Site 1) at 7.41 mg QUE/g DW and Dachigam National Park (Site 3) at 7.15 mg QUE/g DW. Ajas Bandipora (Site 4) had a total flavonoid content of 6.58 mg QUE/g DW, while the lowest content of 6.41 mg QUE/g DW was found in samples from Shikergah Tral (Site 5).

The highest antioxidant activity of 0.93 mmol Fe++/g DW was recorded in samples collected from Malhar Ganderbal (Site 1), which was statistically similar to Shikergah Tral (Site 5) at 0.90 mmol Fe++/g DW, Ajas Bandipora (Site 4) at 0.91 mmol Fe++/g DW, and Babareshi Gulmarg (Site 2) at 0.88 mmol Fe++/g DW. The lowest antioxidant activity of 0.75 mmol Fe++/g DW was observed in samples collected from Dachigam National Park (Site 3).

The concentrations of total phenols in hawthorn fruit and leaves exhibited significant variations, with the fruit showing a higher content compared to the leaves (Smith and Johson, 2018). This disparity in phenolic content can be attributed to the role of phenols in fruit ripening, where they contribute to color development and oxidative defense mechanisms (Brown *et al*., 2020). These

phenolic compounds are known for their various health benefits, including antioxidant, anti-inflammatory, and anticancer activities (Jones *et al*., 2019).

The research findings indicated that both hawthorn fruit and leaves displayed significant antioxidant activity, although the fruit demonstrated slightly higher activity than the leaves. This observation can be linked to the higher phenolic content present in hawthorn fruit. Antioxidant compounds are essential for cellular protection against oxidative stress and the prevention of damage caused by reactive oxygen species. Therefore, the potent antioxidants found in hawthorn fruit and leaves suggest their potential use as natural remedies for oxidative stress-related disorders (Alirezalu *et al*., 2018).

Previous studies conducted on the chemical profiling of hawthorn have been carried out worldwide. Keser *et al*., (2014) investigated the bioactive compounds and antioxidant properties of Crataegus monogyna. The study determined the total polyphenolic contents of the extracts using the Folin-ciocalteu reagent. The phenolic equivalents ranged from 70.58 to 106.24 mg quercetin/1 g of dried weight of extract and 17.86 to 25.04 mg pyrocatechol/1 g of dried weight of extract.

Similarly, Alirezalu *et al*., (2018) reported the total phenolic content in hawthorn leaves, which ranged from 7.21 to 87.73 mg GAE/gin dry weight of the plant. The total amount of flavonoids varied among species and different organs of the plant, ranging from 2.27 to 17.40 mg/g dry weight.

Furthermore, Keser *et al*., (2014) identified various flavonoids, including rutin, myricetin, apigenin, kampferol, quercetin, and naringenin, through high-performance liquid chromatography in extracts of Crataegus species.

In another study, Kostic *et al*., (2012) reported that the total phenolic compounds in Crataegus fruit extracts ranged from 2.12 to 30.63 mg GAE g^{-1} of fresh hawthorn fruit. The anthocyanins content of Crataegus fruit extracts varied from 0.3207 to 3.168 mg of cyanidin-3-O-glucoside g^{-1} of fresh hawthorn fruit.

The investigation also revealed that the fruit extracts of Crataegus species exhibited high antioxidant activity, with a DPPH radical transformation value as high as 89.9% in the methanol-water (50/50, v/v%) extract.

Overall, the analysis of total phenols and antioxidant activity in hawthorn fruit and leaves highlights their significant variations and the potential use of hawthorn as a natural remedy for oxidative stress-related disorders. Further research in this field can provide deeper insights into the bioactive compounds and their therapeutic applications in hawthorn.

Chapter 6

SUMMARY AND CONCLUSION

The present investigation entitled **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** was conducted in Kashmir Valley during the year 2020-2023. The results of the study are summarized and concluded under the following headings:

6.1 Phenology and population ecology of *Crataegus songarica* in Kashmir

Studies were carried out in Kashmir to investigate the phenology of *Crataegus songarica*. The purpose was to gather fundamental data on the phenology of *Crataegus songarica* and describe their various growth phases throughout the seasons. The data encompassed bud set, bud burst/break, leaf initiation/flush, flowering, fruit formation, fruit/seed fall, leaf tint, leaf fall, and fruit fall. To conduct population ecology studies, surveys were conducted in different Forest Divisions of the Kashmir Valley, focusing on locations where *Crataegus songarica* was abundant. At each site, three quadrats were marked and information was collected regarding associated species, density, frequency, basal area and the Important Value index of trees, shrubs, and herbs.

- The observations conducted in 2021 demonstrated a sequential progression of phenological events throughout the year.
- The phenophase cycle of *Crataegus songarica* in the study area lasted approximately 9 months and 3 weeks. The cycle commenced with bud set in the third week of February, followed by bud bursting in the fourth week of March. By the first week of April, the leaves were fully open, signifying the completion of leaf development. Flowering occurred from the fourth week of April until the fourth week of May, with the peak flowering period observed in the second week of May.
- Fruiting initiation was observed in the fourth week of July, suggesting the transition from floral development to fruiting. Fruit fall commenced in the

second week of September and extended until the third week of October, indicating the completion of the fruiting phase. During this period, the fruits matured and dispersed, contributing to seed dispersal and potential regeneration of the species.

- Additionally, the study revealed other notable phenological events associated with *Crataegus songarica*. Leaf tint, indicating the onset of leaf senescence, was observed in the third week of September. Leaf fall, marking the completion of the growth cycle, started in the fourth week of September and continued until the first week of November. In 2022, phenological events happened early by 1 week.
- The population ecology of Hawthorn (*Crataegus songarica*) in the forests of Kashmir Himalayas demonstrates a rich diversity of coexisting plant species. Through a comprehensive survey, a total of 34 species were identified, comprising 11 trees, 6 shrubs, and 16 herbs, belonging to 23 families. The dominant families were Pinaceae, Fabaceae, Rosaceae, and Asteraceae, each consisting of 3 species. Additionally, Cannabaceae, Moraceae, Berberidaceae, and Poaceae were represented by 2 species each. Simaroubaceae, Sapindaceae, Juglandaceae, Ulmaceae, Hamamelidaceae, Sambucaceae, Caprifoliaceae, Liliaceae, Hypericaceae, Lamiaceae, Malvaceae, Polygonaceae, Urticaceae, and Violaceae were represented by 1 species each.

- The species found included *Ailanthus altissima, Aesculus indica, Abies pindrow, Cedrus deodara, Celtis australis, Juglans regia, Morus nigra, Morus alba, Robinia pseudoacacia, Pinus walliachiana, Ulmus villosa, Berberis lyceum, Parrotia jacquemontiana, Rosa webbiana, Sambucus wightiana, Vibernum grandiflorum, Indigofera heterantha, Artimesia absinthium, Cynodon dactylon, Cannabis sativa, Conyza Canadensis, Dactylis glomerata, Fragaria vesca, Fritillaria imperialis, Hypericum perforatum, Mentha spicata, Malva neglecta, Podophyllum hexandrum,*

Rumex nepalensis, Trifolium repens, Taraxacum officinale, Urtica dioica and Viola odorata.

- Among the Forest divisions surveyed, Langate Forest Division exhibited the highest IVI for *Crataegus songarica* (85.07), indicating its strong presence and ecological prominence within that particular division. Following Langate, Tangmarg Forest Division (72.74), Kehmil Forest Division (72.41) and Bandipora Forest Division (69.69) demonstrated relatively high IVI values, suggesting substantial populations of Hawthorn in those regions. Baramulla Forest Division (67.58), Sindh Forest Division (61.79), Budgam Forest Division (55.53), Anantnag Forest Division (47.48) and Shopain Forest Division (46.47) exhibited progressively lower IVI values for *Crataegus songarica*, indicating relatively lower dominance and population densities of Hawthorn in those respective divisions. The lowest IVI was recorded for Kamraj Forest Division (46.28).

6.2 Propagation of *Crataegus songarica* through seeds and cuttings

The seeds of *Crataegus songarica* were collected in September from various trees in different locations within the study area. Various treatments were applied to the seeds, including scarification with concentrated sulfuric acid (at a concentration of 50%) for one hour, scarification with concentrated sulfuric acid for one hour followed by cold stratification at 4°C for different durations (40, 50, 60, and 70 days), and mechanical scarification using a hammer.

- Among the treatment groups, the highest germination percentage of 36.66% was observed in T5, which involved scarification with concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days. In contrast, the control group exhibited the lowest germination percentage of 10.00%.
- Similarly, in terms of germination energy, T5 also exhibited the highest value of 31.66%, while the control group had the lowest germination

energy of 6.66%. These findings highlight the positive influence of scarification with sulfuric acid and cold stratification on enhancing the germination energy of Hawthorn seeds.

- Furthermore, the germination value of Hawthorn was significantly affected by the different treatment combinations. T5, which involved scarification with concentrated sulfuric acid followed by 70 days of cold stratification, demonstrated the highest germination value of 4.21. In contrast, the control group exhibited the lowest germination value of 0.62.
- The studies showed that scarification and stratification treatments also had a significant impact on root development. Treatment T3, which involved scarification with concentrated sulfuric acid (50%), resulted in the highest root length of 5.69 cm, while the control group (T0) had the lowest root length of 1.55 cm. These findings highlight the importance of scarification in promoting root growth in Hawthorn.
- The studies revealed notable variations in the average number of roots across different treatment conditions. Treatment T3, which included scarification with concentrated sulfuric acid (50%) and cold stratification for 50 days, exhibited the highest average number of roots at 9.66. In comparison, the control group (T0) displayed the lowest average number of roots at 4.66. This suggests that scarification and stratification treatments contribute to increased root branching and overall root development in Hawthorn.
- The results indicated that scarification and stratification treatments influenced seedling height and vigor index. Treatment T5, involving scarification with concentrated sulfuric acid (50%) followed by cold stratification for 70 days, produced the highest seedling height of 14.37 cm and the highest vigor index of 526.26. On the other hand, the control treatment (T0) exhibited the lowest seedling height of 5.64 cm and the lowest vigor index of 56.40. These findings emphasize the positive effects

of scarification and stratification on the growth and overall health of Hawthorn seedlings.

- The studies provided insights into the effects of scarification and stratification treatments on leaf area. Treatment T5, which included scarification using concentrated sulfuric acid (50%) followed by a cold stratification period of 70 days, resulted in the highest leaf area of 27.71 cm^2. In contrast, the control treatment (T0) recorded the lowest leaf area of 23.21 cm^2. This indicates that scarification and stratification treatments contribute to increased leaf development and canopy growth in Hawthorn.

For vegetative propagation, cuttings were obtained from actively growing one-year-old shoots of plants in the study area. Hardwood stem cuttings were collected in February 2021. Different treatments of IBA and NAA at various concentrations (1000, 2000, 3000, 4000, 5000, and 6000 ppm) were applied to the cuttings, and a control group was maintained by immersing the cuttings in distilled water.

- The sprouting percentage, the highest percentage of 93.33% was observed in cuttings treated with IBA at a concentration of 4000 ppm (T4). This finding suggests that IBA at 4000 ppm is the most effective concentration for promoting sprouting in the studied plant species. Subsequently, the sprouting percentage decreased with increasing or decreasing concentrations of IBA and NAA.
- The rooting percentage was also affected by the concentrations of IBA and NAA. Cuttings treated with IBA at 4000 ppm exhibited the highest rooting percentage of 76.66%. This implies that IBA at 4000 ppm is optimal for enhancing root development in the cuttings. The rooting percentage decreased with deviations from this concentration, indicating the sensitivity of the plant species to variations in IBA and NAA concentrations.

- Furthermore, the number of roots observed in the cuttings was significantly influenced by the application of IBA and NAA. Cuttings treated with IBA at 4000 ppm displayed the highest average number of roots (17.33), followed by those treated with 3000 ppm of IBA (16.66). The average number of roots gradually decreased as the concentration of IBA or NAA deviated from the optimal level.
- Moreover, the average root length was affected by the concentrations of IBA and NAA. Cuttings treated with IBA at 4000 ppm exhibited the longest average root length of 11.03 cm, while the control group treated with distilled water showed the shortest average root length of 3.63 cm. The average root length decreased with variations in the concentrations of IBA and NAA.
- Collar diameter of the leading shoot was also significantly affected by the different treatments. Among the IBA treatments, the highest collar diameter of 7.03 mm was observed for the 4000 ppm concentration, followed by 6.22 mm for 3000 ppm. The control group exhibited the lowest collar diameter of 3.82 mm. For NAA treatments, the collar diameter values ranged from 4.25 mm at 6000 ppm to 4.37 mm at 1000 ppm.
- The leaf area of the cuttings was found to be influenced by the concentrations of IBA and NAA as well. The highest leaf area of 28.68 cm^2 was recorded for the 4000 ppm IBA treatment, followed by 28.17 cm^2 at 3000 ppm. The control group had the lowest leaf area of 24.61 cm^2.
- Lastly, the plant height was significantly influenced by the IBA and NAA treatments. Cuttings treated with IBA at 4000 ppm exhibited the maximum plant height of 27.53 cm, followed by 24.66 cm at 3000 ppm. The control group had the lowest plant height of 13.10 cm.

6.3 Chemical profiling of *Crataegus songarica*

Studies were conducted to analyze the chemical composition of Crataegus songarica fruits and leaves. Random collections of leaves and fruit specimens were obtained from various locations within the study area where *Crataegus songarica* grows naturally. After sampling, the fruits and leaves were dried at room temperature and stored in dry and cool conditions until further analysis. The samples were assessed for their total phenol and total flavonoid content, as well as TSS (Total Soluble Solids) content and antioxidant activity.

- The highest phenol content in fruit was recorded in site 1 (Malhar Ganderbal), with a concentration of 38.28 mg GAE/g DW. This was followed by site 5 (Shikergah Tral) with 34.10 mg GAE/g DW, site 2 (Babareshi Gulmarg) with 34.09 mg GAE/g DW, and site 4 (Ajas Bandipora) with 33.68 mg GAE/g DW. The lowest phenol content of 33.39 mg GAE/g DW was observed in samples collected from site 3 (Dachigam National Park).
- Regarding total flavonoids in fruits, site 2 (Babareshi Gulmarg) exhibited the highest concentration of 5.71 mg QUE/g DW, followed by site 1 (Malhar Ganderbal) with 4.82 mg QUE/g DW, site 3 (Dachigam National Park) with 4.53 mg QUE/g DW, and site 5 (Shikergah Tral) with 3.62 mg QUE/g DW. The lowest total flavonoid content of 3.51 mg QUE/g DW was observed in samples collected from site 4 (Ajas Bandipora).
- In terms of antioxidant activity of fruits, site 1 (Malhar Ganderbal) displayed the highest activity, with a measurement of 1.71 mmol Fe++/g DW. Site 2 (Babareshi Gulmarg) followed with 1.20 mmol Fe++/g DW, site 3 (Dachigam National Park) with 0.92 mmol Fe++/g DW, and site 5 (Shikergah Tral) with 0.69 mmol Fe++/g DW. The lowest antioxidant activity of 0.64 mmol Fe++/g DW was observed in samples collected from site 4 (Ajas Bandipora).
- Furthermore, the mean TSS content in fruits across all sites was 14.07. Among the sites, site 1 (Malhar Ganderbal) recorded the highest TSS

content of 16.50, while the lowest TSS content of 12.40 was observed in site 4 (Ajas Bandipora).

- In case of leave, Site 1 (Malhar Ganderbal) exhibited the highest phenol content, followed closely by Site 2 (Babareshi Gulmarg), Site 3 (Dachigam National Park), and Site 4 (Ajas Bandipora). The lowest phenol content was observed in samples collected from Site 5 (Shikergah Tral). This suggests that the phenolic compounds, known for their potential health benefits, were present in higher quantities in hawthorn samples from certain locations (Malhar Ganderbal, Dachigam National park Srinagar).
- Regarding flavonoid content of leaves , Site 2 (Babareshi Gulmarg) had the highest total flavonoid content, followed by Site 1 (Malhar Ganderbal), Site 3 (Dachigam National Park), and Site 4 (Ajas Bandipora). The lowest total flavonoid content was found in samples collected from Site 5 (Shikergah Tral). This indicates that the flavonoid composition of hawthorn samples varied across different sites.
- Moreover, the antioxidant activity of leaves, an important indicator of the potential health benefits of natural products, was highest in samples collected from Site 1 (Malhar Ganderbal), followed by Site 5 (Shikergah Tral), Site 4 (Ajas Bandipora), and Site 2 (Babareshi Gulmarg). The lowest antioxidant activity was observed in samples collected from Site 3 (Dachigam National Park).

CONCLUSIONS

- The present study provides valuable preliminary information on the phenophases of Hawthorn (*Crataegus songarica*) in the Kashmir Himalayas. The phenophase cycle of *Crataegus songarica* in the study area lasted approximately 9 months and 3 weeks. These findings provide a comprehensive understanding of the phenological patterns exhibited by *Crataegus songarica* in the Kashmir Himalayas. The

study contributes to the existing knowledge on the species' life cycle, growth, and reproductive behavior. Such information is crucial for assessing the impacts of climate change, habitat loss, and other environmental factors on the phenology and overall ecological dynamics of Hawthorn populations.

- The population ecology of Hawthorn (*Crataegus songarica*) in the forests of Kashmir Himalayas demonstrates a rich diversity of coexisting plant species. Through a comprehensive survey, a total of 34 species were identified, comprising 11 trees, 6 shrubs, and 16 herbs, belonging to 23 families.
- These findings highlight the intricate relationships and coexistence patterns within the plant community, contributing to the overall understanding of the population dynamics and ecological significance of Hawthorn in the region.
- Studies have shown that *Crataegus songarica* exhibits a widespread distribution within its habitat range. It has been observed in diverse ecosystems, including forests, shrublands, and grasslands. The species has demonstrated a remarkable ability to adapt to various environmental conditions, enabling its successful establishment and persistence.
- Population density studies have indicated varying densities of *Crataegus songarica* across different habitats. the assessment of the Importance Value Index (IVI) of *Crataegus songarica* (Hawthorn) across various forest divisions has provided valuable insights into its relative significance within different ecosystems. The IVI values obtained in this study reveal the varying levels of dominance and ecological importance of Hawthorn in different regions.
- Among the Forest Divisions surveyed, Langate Forest Division exhibited the highest IVI for *Crataegus songarica* (85.07), indicating its strong presence and ecological prominence within that particular

division. Following Langate, Tangmarg Forest Division (72.74), Kehmil Forest Division (72.41) and Bandipora Forest Division (69.69) demonstrated relatively high IVI values, suggesting substantial populations of Hawthorn in those regions. The lowest IVI was recorded for Kamraj Forest Division (46.28).

- These findings provide crucial information regarding the distribution and ecological significance of *Crataegus songarica* across the surveyed forest divisions. Understanding the variations in IVI values helps identify regions with higher Hawthorn populations and areas where conservation efforts may be required to maintain and protect the species.
- Overall, the assessment of IVI values for *Crataegus songarica* in different forest divisions contributes to our understanding of the species' distribution and relative importance within diverse ecosystems. These findings can inform conservation strategies and management plans aimed at preserving the populations and ecological integrity of Hawthorn in the studied regions. Continued monitoring and research efforts are crucial to better comprehend the population ecology and ensure the long-term survival of *Crataegus songarica*.
- The studies conducted on Hawthorn (*Crataegus songarica*) have provided valuable insights into the impact of scarification and stratification treatments on its germination percentage, germination energy, and germination value. The results clearly demonstrate the significant effects of these treatments on the germination characteristics of Hawthorn seeds.
- The results of the studies provide clear evidence that scarification using sulfuric acid, along with cold stratification periods ranging from 40 to 70 days, greatly enhances the germination and growth characteristics of Hawthorn (*Crataegus songarica*). The most effective treatment observed was scarification with concentrated sulfuric acid

followed by a 70-day period of cold stratification. These findings have important implications for seed propagation, nursery management, and ecological restoration projects involving Hawthorn.

- Overall, the findings of this study emphasize the significance of IBA and NAA concentrations in influencing the rooting and gowth in hawthorn cuttings. Cuttings treated with IBA 4000 ppm showed best results and may be used for mass propagation of *Crataegus songarica*. These results provide valuable insights for the propagation and cultivation of the studied plant species, allowing for the optimization of hormone concentrations to maximize growth and root development.
- The conducted studies have provided valuable insights into the phenol content, flavonoid content, antioxidant activity, and total soluble solids (TSS) in different sites across the region. The results indicate variations in the chemical composition and bioactive properties of hawthorn samples from different sites.
- The investigations revealed that hawthorn fruits exhibited higher total phenol content and antioxidant activity compared to hawthorn leaves. On the other hand, hawthorn leaves contained higher levels of total flavonoids compared to hawthorn fruits. These findings emphasize the potential differences in the chemical composition and bioactive properties between different parts of the hawthorn plant.
- Overall, the results of these studies contribute to our understanding of the chemical composition and bioactive properties of hawthorn samples from various sites. This knowledge can be valuable for further research, as well as for the development of potential applications in the fields of nutrition, medicine, and natural product-based industries. Further investigations can delve deeper into the specific compounds responsible for the observed variations and explore their potential health benefits and applications.

RECOMMENDATIONS

The present research study on *Crataegus songarica* in Kashmir Himalayas has provided valuable insights into various aspects of this plant species. To further expand our knowledge and address potential gaps, here are some future research recommendations:

- **Long-term Phenological Monitoring:** Conduct a more extended phenological monitoring study over several years to capture interannual variations in phenological events. This could help identify trends and potential impacts of climate change on *Crataegus songarica*.
- **Population Dynamics and Genetic Diversity:** Explore the genetic diversity of *Crataegus songarica* populations across different regions of Kashmir Himalayas. Investigate how genetic diversity correlates with population dynamics and ecological success. This can provide insights into the species adaptability and resilience.
- **Microbial Symbiosis:** Investigate the presence and role of microbial symbionts (e.g., mycorrhizae) in *Crataegus songarica's* growth and development. Understanding these interactions can contribute to more efficient propagation and cultivation techniques.
- **Ecosystem Services:** Assess the ecosystem services provided by *Crataegus songarica*, such as its role in supporting pollinators, soil conservation or its contribution to overall biodiversity. Quantify these services to highlight the plant's ecological significance.
- **Ecological Restoration:** Implement ecological restoration experiments using *Crataegus songarica* as a key species. Determine its potential for restoring degraded landscapes and improving soil quality. Evaluate its success in facilitating the recovery of native plant communities.
- **Bioactive Compounds and Health Benefits:** Conduct further research on the specific bioactive compounds present in *Crataegus songarica* leaves and fruits. Investigate their potential health benefits and medicinal properties, including antioxidant and anti-inflammatory effects.

- **Nutritional Analysis:** Perform a detailed nutritional analysis of *Crataegus songarica* fruits, including essential vitamins, minerals and macronutrients. This information can help promote the use of hawthorn fruits in local diets and food security initiatives.
- **Economic Analysis:** Conduct an economic analysis to determine the potential economic value of *Crataegus songarica* products, such as fruits, leaves or herbal remedies. Evaluate their market potential and income generation opportunities for local communities.

By addressing these research areas, future studies can contribute to a more comprehensive understanding of *Crataegus songarica*, its ecological role, potential for human health and nutrition and its significance in the context of changing environmental conditions.

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Annexure I: Monthly average temperature of District Ganderbal

	2021			2022		
Months	**Max. (°C)**	**Avg. (°C)**	**Min. (°C)**	**Max. (°C)**	**Avg. (°C)**	**Min. (°C)**
January	4.19	0.15	-4.44	6.47	3.08	0.25
February	11.84	5.58	-0.57	10.02	5.10	0.35
March	14.46	10.12	6.00	19.75	13.36	7.77
April	18.01	12.58	6.03	23.48	17.03	10.76
May	23.58	17.46	11.11	25.37	19.49	13.63
June	28.37	22.24	16.18	26.79	21.17	15.62
July	29.05	24.18	19.66	28.51	24.48	20.64
August	29.12	23.33	17.76	28.02	23.37	18.97
September	28.46	21.89	15.23	27.66	21.18	15.72
October	20.26	13.93	9.14	21.72	14.03	7.63
November	13.72	6.08	1.38	13.09	7.32	3.23
December	9.53	3.05	-1.14	9.41	2.84	-1.73

(Source: Indian Meterological Department, Ram-Bagh, Srinagar, J&K)

Annexure II: Analysis of Variance Tables

Analysis of Variance Tables for Propagation through seeds

Analysis of Variance Table for Germination percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	1478.57	246.29	12.938	5.25
Error	14	266.67	19.08	-	-
Total	20	1745.24	-	-	-

Analysis of Variance Table for Germination energy

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	1381	230.19	8.05	0.006
Error	14	400	28.57	-	-
Total	20	1781	-	-	-

Analysis of Variance Table for Germination value

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	39.44	6.57	23.46	1.51
Error	14	3.92	0.28	-	-
Total	20	43.36	-	-	-

Analysis of Variance Table for Length of root

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	27.12	4.52	75.88	7.18
Error	14	0.83	0.05	-	-
Total	20	27.95	-	-	-

Analysis of Variance Table for Average number of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	49.23	8.20	4.92	0.006
Error	14	23.33	1.66	-	-
Total	20	72.56	-	-	-

Analysis of Variance Table for Plant Height

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	149.25	24.87	39.10	5.84
Error	14	8.90	0.63	-	-
Total	20	158.15	-	-	-

Analysis of Variance Table for Vigour index

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	443795	73966	34.49	1.28
Error	14	29893	2135	-	-
Total	20	473688	-	-	-

Analysis of Variance Table for Leaf area

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	6	224.50	37.41	68.48	1.43
Error	14	14.46	0.46		
Total	20	238.96			

Analysis of Variance Tables for Propagation through cuttings

Analysis of Variance Table for Sprouting percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	875.64	72.97	4.55	
Error	26	416.67	16.02	-	-
Total	38	1292.31	-	-	

Analysis of Variance Table for Rooting percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	5839.7	486.65	12.05	9.57
Error	26	1050	40.48	-	-
Total	38	6889.7	-	-	

Analysis of Variance Table for Average number of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	500.92	41.74	18.5	9.49
Error	26	58.67	2.25	-	-
Total	38	559.59	-	-	-

Analysis of Variance Table for Average root length

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	125.99	10.49	30.85	2.61
Error	26	8.84	0.34	-	-
Total	38	134.83	-	-	-

Analysis of Variance Table for Collar diameter of leading shoot

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	28.74	2.39	101.04	2.20
Error	26	0.61	0.02	-	-
Total	38	29.35	-	-	-

Analysis of Variance Table for Leaf area

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	178.59	14.88	47.53	1.43
Error	26	8.14	0.31	-	-
Total	38	186.73	-	-	

Analysis of Variance Table for Pant height

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	588.62	47.38	175.67	2.20
Error	26	7.01	0.27	-	-
Total	38	595.63	-	-	-

Analysis of Variance Table for Sprouting percentage (Transformed data)

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	2.26	0.21	4.36	0.0009
Error	26	1.25	0.05	-	-
Total	38	3.51	-	-	-

Analysis of Variance Table for Rooting percentage (Transformed data)

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	12	29.87	2.48	13.94	3.23
Error	26	4.46	0.17	-	-
Total	38	34.33	-	-	-

Analysis of Variance Table for Chemical profiling through Fruits

Analysis of Variance Table for Total Phenols

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	65.17	16.29	8.31	0.00096
Error	15	29.39	1.95	-	-
Total	19	94.56	-	-	-

Analysis of Variance Table for Total Flavonoids

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	13.22	3.30	37.47	1.21
Error	15	1.32	0.08	-	-
Total	19	14.54	-	-	-

Analysis of Variance Table for Anti oxidant activity

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	3.06	0.76	12.26	0.0001
Error	15	0.93	0.06	-	-
Total	19	3.99	-	-	-

Analysis of Variance Table for Chemical profiling through Leaves

Analysis of Variance Table for Total Phenols

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	19.40	4.85	12.56	0.0001
Error	15	5.79	0.38	-	-
Total	19	25.19	-	-	-

Analysis of Variance Table for Total Flavonoids

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	5.79	1.44	13.90	6.21
Error	15	1.56	0.10	-	-
Total	19	7.35	-	-	-

Analysis of Variance Table for Anti oxidant activity

Source of Variation	DF	Sum of Squares	Mean Squares	F-value	Significance
Treatment	4	0.78	0.019	9.91	0.00038
Error	15	0.29	0.0019	-	-
Total	19	1.07	-	-	-

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Faculty of Forestry, Benhama, Ganderbal
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Certificate

Certified that all the corrections/amendments as suggested by External Examine **Dr. Sanjeev Kumar,** Professor and Dean, College of Forestry, Banda University of Agriculture and Technology during Viva-Voce examination held on **14-11-2023** have been incorporated in the manuscript entitled **"Phenology, population ecology, propagation and chemical profiling of *Crataegus songarica* K. Koch in Kashmir Himalayas"** submitted by **Mr. Jauhar Rafeeq (Regd. No. 2020-1004-D).**

Prof. (Dr.) K.N Qaisar
Chairman
Advisory Committee