

**RESPONSE OF *Melia dubia* AND *Dalbergia sissoo* TO
SANDY LOAM SOIL AMENDED WITH WATER
ABSORBANT POLYMERS**

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
FORESTRY
(Minor Subject: Botany)**

By

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2022

CERTIFICATE - I

This is to certify that the thesis entitled “**Response of *Melia dubia* and *Dalbergia sissoo* to sandy loam soil amended with water absorbant polymers**” submitted for the degree of **Master of Science** in the subject of **Forestry** (Minor subject: **Botany**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Rajesh Kumar (L-2019-H-171-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE - II

This is to certify that the thesis entitled “**Response of *Melia dubia* and *Dalbergia sissoo* to sandy loam soil amended with water absorbant polymers**” submitted by **Rajesh Kumar (L-2019-H-171-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Forestry** (Minor subject: **Botany**) has been approved by the Student’s Advisory Committee after an oral examination on the same.

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ACKNOWLEDGEMENT

Foremost of all, I express my sincere gratitude to the “AKAL PURKH” for his benign blessing hand and bestowing a healthy and creative environment throughout my carrier.

*Words are compendious in expressing my profound indebtedness to my major advisor **Dr. Ashok Kumar Dhakad, Tree Breeder, Dept. of Forestry & Natural Resource**, who is objective and humanitarian in principles, for her scholarly guidance in shaping the dissertation in this form. Her ability, perseverance, parental inspiration, constant encouragement, invaluable suggestions and administrative help sustained my efforts for completion of this work in time. I consider myself fortune.*

*In recognition to the support and help extended by my advisory committee members namely **Dr. Sapna Thakur, Assistant Professor (Forestry), Dr. Nirmaljit Kaur (Principal Botanist), Dr. Harmeet Singh Saralch (Professor, Forestry), and Dr. Avtar Singh (Principal Silviculturist)**. I am grateful to them for their able guidance, kind suggestions during the course of investigation.*

*My vocabulary utterly fails in expressing my profound gratitude to my supportive and loving family; my father **Mr. Dev Raj**, my mother **Smt. Durga Rani** whose unconditional love and sacrifice can never be forgotten whose ever willing help has a great role in my life endeavors.*

*A word of appreciation will not compensate for the ever willing help and cooperation by my friends **Amanpal Singh, Manpreet Singh and Simardeep Singh**. A special thanks to all my seniors for their support and for the memorable moments during my degree programme.*

***Mr. Deepak Kumar and Mr. Beer Bahadur** (Ekta Computer Centre, Opp. P.A.U. Gate No.3, Ludhiana) deserve special thanks for bringing out this manuscript in its presentable form.*

Everyone must have not been mentioned but none is forgotten.

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Degree to be awarded : M.Sc. (Forestry)

Year of award of degree : 2022

Total pages in Thesis : 61 + VITA

Name of the University : Punjab Agricultural University, Ludhiana

ABSTRACT

The present study was carried out in the Department of Forestry & Natural Resources at Punjab Agricultural University, Ludhiana during the year 2021-22. To study the effect of water absorbant polymers application on the growth, biomass, elemental concentrations in leaves and leaf physiological parameters of *Melia dubia* and *Dalbergia sissoo*, the hydrogel was applied in powdered form before planting the seedlings in pits having 50×50×50 cm³ volume at concentrations of 0, 25, 30, 35, 40, 45 and 50 g/plant. Plant characteristics like plant height, collar diameter, leaf N, P, K, and physiological traits viz., chlorophyll, carotenoids, RWC, MSI and TSS were measured at 6 months or seasonal interval, while, CAI for height and diameter, crown length, crown height, root length, plant fresh and dry weight were at end of experiment (12 MAP). In *Melia dubia*, treatment T2 (30 gm/pit) was found best for growth and biomass parameters and lowest values was in control. However, in *Dalbergia sissoo* maximum readings of growth and biomass parameters were obtained in Treatment T3 (35 gm/pit) and minimum in control. The physiological parameters of *Melia dubia* such as N, K, RWC and MSI were recorded higher in T2 (30 gm/pit) while P was in T3 (35 gm/pit) treatment. Total carotenoid was recorded maximum for both T2 (30 gm/pit) and T3 (35 gm/pit). Chl-a, Chl-b and total chlorophyll were observed highest in T6 (50 gm/pit) and TSS was in T1 (25 gm/pit). The physiological parameters of *Dalbergia sissoo* did not show any definite pattern for most of the traits studied. The maximum value of N and MSI was observed in T4 (40 gm/pit), while P and K were in T2 (30 gm/pit). Chl-a, Chl-b, total chlorophyll and RWC were found maximum in T3 (30 gm/pit), total carotenoids in T6 (50 gm/pit) and TSS in T1 (25 gm/pit). Lowest values for all physiological parameters in both trees were recorded under control. The high heritability was recorded in root length, plant fresh, dry weight and few physiological traits for both *Melia dubia* and *Dalbergia sissoo*. Only growth and biomass traits showed significant positive correlation in both plant species.

Keywords: *Melia dubia*, *Dalbergia sissoo*, hydrogel application, growth, leaf mineral, physiology.

Signature of Major Advisor

Signature of the Student

ਖੇਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	:	ਮੇਲੀਆ ਡੁਬੀਆ ਅਤੇ ਡਾਲਬਰਗੀਆ ਸਿਸੂ ਪੌਦਿਆਂ 'ਤੇ ਰੇਤਲੀ ਦੇਮਟ ਮਿੱਟੀ ਵਿੱਚ ਪਾਣੀ ਸੋਖਣ ਵਾਲੇ ਪੌਲੀਮਰਾਂ ਦਾ ਪ੍ਰਭਾਵ
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ਮੁੱਖ ਵਿਸ਼ਾ	:	ਜੰਗਲਾਤ
ਸਹਿਯੋਗੀ ਵਿਸ਼ਾ	:	ਬਨਸਪਤੀ ਵਿਗਿਆਨ
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ਡਿਗਰੀ ਪ੍ਰਦਾਨ ਕੀਤੀ ਜਾਵੇਗੀ	:	ਐਮ.ਐਸ.ਸੀ. (ਜੰਗਲਾਤ)
ਡਿਗਰੀ ਮਿਲਣ ਦਾ ਸਾਲ	:	2022
ਖੇਜ ਗ੍ਰੰਥ ਵਿੱਚ ਕੁੱਲ ਪੰਨੇ	:	61 + ਵੀਟਾ

ਸਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ ਸਾਲ 2021-22 ਦੇ ਦੌਰਾਨ ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਜੰਗਲਾਤ ਅਤੇ ਕੁਦਰਤੀ ਸਰੋਤ ਵਿਭਾਗ ਵਿੱਚ ਕੀਤਾ ਗਿਆ ਸੀ। ਜਲ ਸੋਖਣ ਵਾਲੇ ਪੌਲੀਮਰਾਂ ਦੀ ਵਰਤੋਂ ਦਾ ਪ੍ਰਭਾਵ ਬਰਮਾ ਡੇਕ ਅਤੇ ਟਾਹਲੀ ਦੇ ਵਾਧੇ, ਬਾਇਓਮਾਸ, ਪੱਤਿਆਂ ਵਿੱਚ ਤੱਤ ਦੀ ਗਾੜ੍ਹਾਪਣ ਅਤੇ ਪੱਤਿਆਂ ਦੇ ਸਰੀਰਕ ਮਾਪਦੰਡਾਂ 'ਤੇ ਦੇਖਿਆ ਗਿਆ। ਜਲ ਸੋਖਣ ਵਾਲੇ ਪੌਲੀਮਰਾਂ ਨੂੰ ਪਾਊਡਰ ਫਾਰਮ ਵਿੱਚ 0, 25, 30, 35, 40, 45 ਅਤੇ 50 ਗ੍ਰਾਮ/ਪੈਦੇ ਦੇ ਹਿਸਾਬ ਨਾਲ 50 × 50 × 50 cm³ ਵਾਲੀਅਮ ਵਾਲੇ ਟੋਇਆਂ ਵਿੱਚ ਪਾਇਆ ਗਿਆ ਸੀ। ਪੌਦਿਆਂ ਦੀਆਂ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਜਿਵੇਂ ਕਿ ਪੌਦਿਆਂ ਦੀ ਉਚਾਈ, ਕਾਲਰ ਵਿਆਸ, ਪੱਤਾ N, P, K, ਅਤੇ ਸਰੀਰਕ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਜਿਵੇਂ ਕਿ, ਕਲੋਰੋਫਿਲ, ਕੈਰੋਟੀਨੋਇਡਜ਼, RWC, MSI ਅਤੇ TSS ਨੂੰ 6 ਮਹੀਨਿਆਂ ਜਾਂ ਮੌਸਮੀ ਅੰਤਰਾਲ 'ਤੇ ਮਾਪਿਆ ਗਿਆ ਸੀ, ਜਦਕਿ, ਕੁਲ ਉਚਾਈ ਅਤੇ ਵਿਆਸ, ਤਾਜ ਦੀ ਲੰਬਾਈ, ਤਾਜ ਦੀ ਉਚਾਈ, ਜੜ੍ਹ ਦੀ ਲੰਬਾਈ, ਪੈਦੇ ਦੇ ਤਾਜੇ ਅਤੇ ਸੁੱਕੇ ਭਾਰ ਵੇਰਵਾ ਪ੍ਰਯੋਗ ਦੇ ਅੰਤ ਵਿੱਚ ਸਨ (12 MAP)। ਬਰਮਾ ਡੇਕ ਵਿੱਚ ਟ੍ਰੀਟਮੈਂਟ T2 (30 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿਕਾਸ ਅਤੇ ਬਾਇਓਮਾਸ ਮਾਪਦੰਡਾਂ ਲਈ ਸਭ ਤੋਂ ਵਧੀਆ ਪਾਇਆ ਗਿਆ ਅਤੇ ਸਭ ਤੋਂ ਘੱਟ ਮੁੱਲ ਕੰਟਰੋਲ ਵਿੱਚ ਸਨ। ਹਾਲਾਂਕਿ, ਟਾਹਲੀ ਵਿੱਚ ਵਾਧੇ ਅਤੇ ਬਾਇਓਮਾਸ ਮਾਪਦੰਡਾਂ ਦੀ ਅਧਿਕਤਮ ਰੀਡਿੰਗ ਟ੍ਰੀਟਮੈਂਟ ਟੀ3 (35 ਗ੍ਰਾਮ/ਪਿੱਟ) ਅਤੇ ਘੱਟੋ-ਘੱਟ ਕੰਟਰੋਲ ਪ੍ਰਾਪਤ ਕੀਤੀ ਗਈ ਸੀ। ਬਰਮਾ ਡੇਕ ਦੇ ਸਰੀਰਕ ਮਾਪਦੰਡ ਜਿਵੇਂ ਕਿ N, K, RWC ਅਤੇ MSI ਨੂੰ T2 (30 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਉੱਚ ਦਰਜ ਕੀਤਾ ਗਿਆ ਸੀ ਜਦੋਂ ਕਿ P T3 (35 ਗ੍ਰਾਮ/ਪਿੱਟ) ਟ੍ਰੀਟਮੈਂਟ ਵਿੱਚ ਸੀ। T2 (30 ਗ੍ਰਾਮ/ਪਿੱਟ) ਅਤੇ T3 (35 ਗ੍ਰਾਮ/ਪਿੱਟ) ਦੋਵਾਂ ਲਈ ਕੁੱਲ ਕੈਰੋਟੀਨੋਇਡ ਵੱਧ ਤੋਂ ਵੱਧ ਦਰਜ ਕੀਤਾ ਗਿਆ ਸੀ। Chl-a, Chl-b ਅਤੇ ਕੁੱਲ ਕਲੋਰੋਫਿਲ T6 (50 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਸਭ ਤੋਂ ਵੱਧ ਦੇਖਿਆ ਗਿਆ ਸੀ ਅਤੇ TSS T1 (25 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਸੀ। ਟਾਹਲੀ ਦੇ ਸਰੀਰਕ ਮਾਪਦੰਡਾਂ ਨੇ ਅਧਿਐਨ ਕੀਤੇ ਗਏ ਜ਼ਿਆਦਾਤਰ ਗੁਣਾਂ ਲਈ ਕੋਈ ਨਿਸ਼ਚਿਤ ਪੈਟਰਨ ਨਹੀਂ ਦਿਖਾਇਆ। N ਅਤੇ MSI ਦਾ ਅਧਿਕਤਮ ਮੁੱਲ T4 (40 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਦੇਖਿਆ ਗਿਆ, ਜਦੋਂ ਕਿ P ਅਤੇ K T2 (30 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਦੇਖਿਆ ਗਿਆ। Chl-a, Chl-b, ਕੁੱਲ ਕਲੋਰੋਫਿਲ ਅਤੇ RWC T3 (30 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਵੱਧ ਤੋਂ ਵੱਧ, T6 (50 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ ਕੁੱਲ ਕੈਰੋਟੀਨੋਇਡ ਅਤੇ T1 (25 ਗ੍ਰਾਮ/ਪਿੱਟ) ਵਿੱਚ TSS ਪਾਏ ਗਏ। ਦੋਵਾਂ ਰੁੱਖਾਂ ਵਿੱਚ ਸਾਰੇ ਸਰੀਰਕ ਮਾਪਦੰਡਾਂ ਲਈ ਸਭ ਤੋਂ ਘੱਟ ਮੁੱਲ ਨਿਯੰਤਰਣ ਵਿੱਚ ਦਰਜ ਕੀਤੇ ਗਏ ਸਨ। ਰੂਟ ਦੀ ਲੰਬਾਈ, ਪੈਦੇ ਦੇ ਤਾਜੇ ਅਤੇ ਸੁੱਕੇ ਭਾਰ, ਬਰਮਾ ਡੇਕ ਅਤੇ ਟਾਹਲੀ ਦੋਵਾਂ ਲਈ ਕੁਝ ਸਰੀਰਕ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਵਿੱਚ ਉੱਚ ਵਿਰਾਸਤੀਤਾ ਦਰਜ ਕੀਤੀ ਗਈ ਸੀ। ਸਿਰਫ ਵਿਕਾਸ ਅਤੇ ਬਾਇਓਮਾਸ ਗੁਣਾਂ ਨੇ ਪੌਦਿਆਂ ਦੀਆਂ ਦੋਨਾਂ ਕਿਸਮਾਂ ਵਿੱਚ ਮਹੱਤਵਪੂਰਨ ਸਕਾਰਾਤਮਕ ਸਬੰਧ ਦਿਖਾਇਆ।

ਮੁੱਖ ਸ਼ਬਦ: ਬਰਮਾ ਡੇਕ, ਟਾਹਲੀ, ਜਲ ਸੋਖਣ ਵਾਲੇ ਪੌਲੀਮਰ, ਵਾਧਾ, ਪੱਤਾ ਤੱਤ, ਸਰੀਰ ਵਿਗਿਆਨ

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LIST OF ABBREVIATIONS AND SYMBOLS

Sr. No.	Abbreviation	Meaning
1.	cm	Centimeter
2.	m	Meter
3.	mm	Millimeter
4.	g	Gram
5.	kg	Kilogram
6.	%	Per cent
7.	Anon	Anonymous
8.	<i>i.e.</i>	That is
9.	<i>etc.</i>	etcetera (and so on)
10.	/	Per

CHAPTER-I

INTRODUCTION

Trees are a critical part of life on our planet because of their several direct and indirect benefits to the humankind and animal world as well. They deliver wood for making houses, furniture, timber, agricultural gear, plywood, paper, veggies, fiber, fuel wood, and many others uses. Other important benefits consist of the supply of oxygen, carbon sequestration, providing a haven to wild fauna, and enhancing soil fertility, which ultimately helps in maintaining the ecological balance of the surroundings. Punjab is an agriculture extensive state having ~84% of its area under cultivation and 2.26% area is covered with trees outside its natural forests. Forest cover in the state is approximately 5.93% of the total geographical area and the maximum area is in the Hoshiarpur district including TOF (ISFR 2021). Increased air pollution and high deforestation in Punjab state create an unstable environment to live in. Thus, planting trees has enormous importance and may increase the area under trees. To increase the area under tree cover from 6 to 15 percent, the Punjab government launched a major afforestation initiative 'Greening Punjab Mission' in 2012. To enhance the green environment and make it healthier, an app has been developed by the forest department of Punjab under 'Mission Tandrust' or 'Mission Healthy' named 'i-Haryali'. This app was launched under the 'ghar-ghar hariyali' or 'door to door greening' scheme which is part of 'Mission Healthy' or 'Mission Tandrust' (<https://forest.punjab.gov.in/en/gallery/video-gallery/iharyali/>).

Water availability is a major challenge to afforestation programs in many parts of the tropical and temperate regions in the world especially in the seedling stage while seedling requires frequent irrigation during summer months. If water is scanty in that region then water-saving technologies that enhance plant establishment and growth in low textured and poor soils of different properties are required. Soils generally differ in moisture content, temperature, and mineralogy (Six *et al* 2022) which may require different soil moisture conservation technologies. One available technology is the use of super absorbent hydrophilic polymers (Dorraji *et al* 2010). Super absorbent polymers (SAPs) are substances that can retain large quantities of water and nutrients when incorporated into the soil, making them available for plant growth whenever required. Several studies have shown that the addition of hydrogels to growing soil media increased water holding capacity by up to 400% (Johnson 1984) and decreased water stress by delaying the onset of wilting (Gehring and Lewis 1980).

Trees grown in soils amended with hydrogel demonstrated improved physiological and morphological traits and thus increased survival of tree seedlings, water-use efficiency by reducing evapotranspiration, and dry matter production under drought conditions (Agaba *et al* 2010; Azevedo *et al* 2016; Coello *et al* 2018). Tomaskova *et al* (2020) stated that hydrogel

efficacy depends upon the tree species' susceptibility to soil and climate stress conditions. Several researchers like Orikiriza *et al* (2009), Agaba *et al* (2010), Orikiriza *et al* (2013), Felipe *et al* (2016) revealed that how hydrogel treatments (in combination with sawdust, biofertilizers, compost, wheat straw, subsoil, or subsoil with a cobble layer) affected the survival, growth, and physiological characteristics in different tree species after planting. Drought-sensitive and drought-tolerant tree species showed their behavioral changes in the growth pattern. Similarly, short and long rotation tree species showed a varying level of growth response against these hydrogel where the climate is temperate type. This creates the baseline for the studies of the hydrogel at different concentrations in soils of different climatic regions and in different soil media compositions where moisture is a limiting factor for the successful establishment of plantations.

Melia dubia is a highly fast-growing tree species and commonly known as Malabar neem and an indigenous species to southern Asia (India, Iran and Pakistan) and has been successfully introduced outside of its natural range (Ram *et al* 2014). The tree can be cultivated in all types of soil and requires a low supply of water initially. It is a multi-purpose tree used for bioenergy production, paper, and pulp production, furniture making, building construction and making musical instruments, etc (Meena *et al* 2014a; Chauhan *et al* 2018). Other than its industrial and commercial importance, the plant has proficient medicinal properties (Sharma and Arya 2011) and pesticide uses (Koul *et al* 2002; Kulawardhana *et al* 2018). *Melia dubia* has propagated through seeds, which have very poor (14-34.3%) germination because of the hard stony seed coat, which makes it difficult to germinate without any treatment (Nair *et al* 2005; Anand *et al* 2012). *Melia dubia* is identified as fast growing with amazing growth characteristics, thereby has gained tremendous confidence of farmers and planters in the last decade (Meena *et al* 2014b).

Dalbergia sissoo is long rotation tree species indigenous to the sub-Himalayan tract in India and Pakistan, growing naturally here. It has been established in irrigated plantations, along roadsides and canals, and around farms and orchards as windbreaks. The economic impacts of *D. sissoo* on a global level are almost exclusively positive. It is a highly valued hardwood timber species, providing an additional income source in agroforestry systems, mostly in India and Pakistan, and increasing elsewhere. According to Tewari (1994), shisham is a friend of the farmer, as well as the forester; a tree that pays rich dividends. Being a nitrogen-fixing species widely used in agroforestry, this plant is acknowledged for its environmental benefits, increasing soil fertility and reducing soil erosion (Singh *et al* 2020). It is a slow-growing tree species and it has a poor straightness score which is a major drawback for its cultivation under Punjab conditions. Punjab Agricultural University is working on its genetic improvement of it by selecting plus trees, new introductions, progeny evaluation, and developing of new clones (Sidhu *et al* 2006; Monga *et al* 2017; Singh *et al* 2020).

Punjab is the only state having a large area under poplar based agroforestry system and played a vital role in the diversification of the rice-wheat-based cropping system to reduce water consumption and replenish the nutritional status of soil (Chauhan *et al* 2012). The over-exploitation of only a few commercially productive Poplar clones and a ban on the cultivation of *Eucalyptus* on productive farmlands and roadside plantations, short rotation tree species like *Melia* and other native tree species like *Dalbergia* may be used to increase the farm income through incorporating these tree species in agroforestry practices. From the harvesting of wheat to paddy planting season (April to June); agroforestry trees experience severe drought. In that situation, the chances of survival and growth of 1-2 years plants are decreased or sometime dieback of the leading shoot has observed so we have to use lighter frequent irrigation or some water saving techniques like water absorbent polymers. Thus, the present study had been planned to evaluate the growth and physiological response of *Melia dubia* and *Dalbergia sissoo* planted in sandy loam soil amended with water absorbent polymers.

CHAPTER-II

REVIEW OF LITERATURE

The review of literature provides basis for preparing the research proposal and conceptualization of different ideas given by different researchers. In the present study, the relevant literature with particular focused on effect of hydrogel in different concentrations used in soil to increase the water retention capacity of soil is summarized and has been reviewed in this chapter.

Wang and Boogher (1987) reiterated the utility and experiments conducted on Agrosoke, a completely expanded hydrogel, was used to replace 5% (1X) or 10% (2X) of the volume of a potting medium to see how it affected plant growth and water use. Despite the fact that Agrosoke had no effect on irrigation frequency, spider plants (*Chlorophytum comosum* (Thunb.) Jacques 'Vittatum') growing in the 2 x medium were 50% bigger, had more lateral shoots, and had better root systems than the control, indicating greater water use efficiency. Agrosoke had no influence on Boston fern (*Nephrolepis exaltata* (L.) Schott. 'Rooseveltii') irrigation frequency or fresh weight. The electrical conductivity of leachates from hydrogel-amended media was greater, indicating that these media carried more nutrients and other salts.

The effect of two water-absorbing artificial polymers, polyacrylamide and polyvinyl alcohol at two concentrations (0.2% and 0.5% v/v) was tested on transplanted seedlings of *Eucalyptus microtheca* receiving a range of irrigation interval. Both polymers aided survival and boom. In the absence of irrigation, polymer components almost doubled the length of tree survival, while underneath frequent irrigation the transplant surprise became reduced. Whilst irrigated every 6 days, all the control seedlings died while those with polymer additives finished 57-71 % survival (Callaghan *et al* 1989).

Raja and Reddy (1990) observed that application of water absorbing polymer Jalshakti did not shown any positive response on the grain yield of maize. Trials conducted on Rice to reduce the irrigation by using 7.5 kg per ha Jalshakti. The result showed that by giving equal irrigation to the treated plots and control, treated plots given doubled yield as compare to control (Anon 1987). Sing and Shaktawat (1990) observed that application of 8 kg per hectare Jalshakti increase the yield of barley and also produced higher dry matter at 60, 90 DAS as compared to application of 4 kg Jalshakti per hectare and control.

Woodhouse and Johnson (1991) described the effects of two water absorbing polymers on growth of sycamore (*Acer pseudoplatanus* L.) and common osier (*Salix viminalis* L.). Both polymers improved growth under each irrigation regime. The polymers were particularly beneficial under infrequent irrigation, where they buffered the trees against the effects of short-term drought. It seems probable that cost-effective applications of polymers could be

made to aid tree growth and to improve survival rates of newly planted trees.

At government nursery, Kohlapur an experiment was conducted which showed that saplings of Jambhul, Ashok, Sandalwood and Bamboo which were treated with 3-4 grams of Jalshakti per plant by hole method remained alive upto 50 days. After 89 days also out of fifteen treated plants, 5 of bamboo, 11 of sandalwood and 1 of jambhul remained alive, whereas 4 sandalwood and 3 bamboo were survived. After the day of transplanting no irrigation was given to any plant (Anon. 1987). Gupta and Singh (1996) reported that incorporation of 'Jalshakti', a water absorbent compound at 20 g per 8 kg soil significantly reduce the primary incidence of downy mildew. Reduction in disease incidence was 72.3 per cent at 30 days after sowing (DAS) and 59.3 per cent at 42 DAS as compared to control.

Huttermann *et al* (1999) studied the effect of an amendment of a sandy soil with superabsorbent hydro gels (Stockosorb K 400) on the survival of *Pinus halepensis* seedlings during water stress. The following concentrations added to the soils: 0.04%, 0.08%, 0.12%, 0.20%, and 0.40%. The water retention of the soil increased with increasing additions of hydro gel to the soil. During desiccation under controlled conditions, the seedlings treated with 0.4% hydro gel survived twice as long in the soils amended with 0.4% hydro gel as in the control soils. The data indicate that an amendment of soils with this type of hydro gels at 0.4% (w/w) will greatly enhance the drought tolerance of the seedlings growing on this substrate.

Youssef (2002) reiterated the effects of several hydrogel compounds: nutrients-free or nutrient hydrogels; at various concentrations: 0.0 percent (control), 0.5 percent, 1.0 percent, or 1.5 percent w/w of peat moss on the acclimatization behaviour of *Acacia melanoxylon* plants were investigated. The acclimation capability of in vitro plants treated with 1.5 percent nutritional hydrogels grew to 2.7-fold greater than that of the control treatment, according to statistical analysis of the data. When compared to the control, all of the hydrogels tested considerably enhanced root length. Despite this, the stem length, number of leaves, and dry weight of plants were unaffected. The highest concentrations of (chlorophyll-A, total indoles, and phenols) or (chlorophyll-B and carotenoids) were found in tissues of in vitro plants treated with 1.0 percent or 0.5 percent nutrient-free hydrogels, respectively.

Viero *et al* (2002) reported increase in tree growth and survival of *Eucalyptus grandis* by the addition of a soil-amended hydrogel (stockosorb 400k) and comparing it to conventional planting methods. Five ranges of water (0 ml, 500 ml, 1000 ml, 2000 ml and 4000 ml) had been blended with five doses of hydro gel (0 g, 3g, 6 g, 9 g, and 12 g). There have been significant variations between control and water doses while in comparison with all degrees of hydro gel, with the hydro gel application plants performed substantially better.

Chen *et al* (2003) reported the effects of hydro gel on growth and ion relationships of a salt resistant woody species *Populus euphratica*, under saline conditions. Amendment of

saline soil with 0.6% hydro gel improved seedling growth (2.7-fold higher biomass) over a period of 2 years, even though plant growth was reduced by salinity. Hydro gel-treated plants had approximately 3.5-fold higher root length and root surface area than those grown in saline soil. In addition, over 6% of total roots were aggregated in gel fragments. Tissue and cellular ion analysis showed that growth improvement appeared to be the result of increased capacity for salt exclusion and enhancement of Ca^{2+} uptake. Hydro gel treatment enhanced uptake of Ca^{2+} . Hydro gel amendment improves the quality of soil solutions by lowering salt level as a result of its salt-buffering capacity and enriching Ca^{2+} uptake, because of the polymer's cation exchange character.

Arbona *et al* (2004) studied that the substrate amendment promoted plant survival of citrus seedlings subjected to several cycles of drought stress and rehydration. In budded trees, the amendment increased substrate water content, leaf water potential, leaf number, root biomass, CO_2 assimilation and stomata conductance over that of control plants growing in non-amended substrates. We conclude that the substrate amendment reduced the damaging effects of drought stress in citrus plants. The longer survival of seedlings in the amended treatment together with the reduction in leaf abscission and the improvement of physiological parameters, can account for a higher vigour of citrus grown under water stress conditions.

Arbona *et al* (2004) evaluated that citrus physiology; production, fruit size, and quality are all affected by water deficiencies. Citrus may respond to drought stress by regulating water status and leaf abscission via endogenous hormones. It was investigated that the effectiveness of a soilless media amendment in delaying the drought stress had a serious impact on young citrus seedlings and plants. Citrus seedlings that were treated to numerous cycles of drought stress and rehydration benefited from a substrate amendment. When compared to control plants growing in non-amended substrates, the amendment enhanced substrate water content, leaf water potential, leaf number, root biomass, CO_2 assimilation, and stomata conductance in budded trees. It was revealed that adding a substrate amendment to citrus plants decreased the negative impacts of drought stress. The enhanced vigor of citrus grown under water stress circumstances can be attributed to the longer survival of seedlings in the adjusted treatment, as well as a reduction in leaf abscission and improvements in physiological indicators.

Solaimalai and Subburamu (2004) studied that seed hardening with NaCl , Na_2SO_4 , KCl , MgSO_4 , KH_2PO_4 , K_2SO_4 , CaCl_2 , Na_2HPO_4 , nitric acid, succinic acid, auxins, CCC, Jalshakthi, triazoles, cow's urine and cow dung extract make crop plants resistant to soil moisture stress. Number of physico-chemical changes within the cytoplasm due to pre sowing treatment which make seed more resistant to water stress. It improves seed viability as well as vigour, root length, root shoot ratio and yield of rain fed crops. Ghugare *et al* (1988) reported application of Jalshakti did not show any effect on the yield of wheat and use of water to

produce per unit of biomass.

Viero and Little (2006) reported that the use of hydro gels (Stockosorb® 400K) at planting, shown improvements in seedling survival and initial growth when planted under adverse conditions. The reformulation of this hydro gel through the addition of plant nutrients (Aquasoil™) was marketed to enhance initial growth whilst retaining the inherent benefits of the hydro gel component. The application of a hydro gel (Stockosorb® 400K) consistently increased seedling survival and initial growth during sub-optimal planting conditions. The surface application of granular fertilizer (whether used in combination with water or a hydro gel) at planting produced the fastest and largest growth responses of all treatments and the use of Aquasoil™ (hydro gel combined with nutrients) to significantly improve survival and initial growth produced inconsistent results when compared to the application of a hydro gel only.

Sarvas *et al* (2007) explained various revelations displayed by findings regarding reclamative use of hydrogels which had an effect on pine seedling survival throughout two vegetative cycles following planting. In comparison to control versions, double application of Stockosorb Agro (gel) to the root system after lifting resulted in a 19% greater survival rate. The use of 7 g of Stockosorb Micro granules per planting hole resulted in over dosage and plant death. The application of hydrogel granules is straightforward, however due to the great swelling capacity of hydrogel, it is extremely difficult not to induce over dosage. Hydrogel application rates for various environmental circumstances and tree types should be determined through research. It will be a major effort to develop a technology with attention to the economic effectiveness of its implementation.

Koupai *et al* (2008) evaluated that hydrogels were tested for their impact on the soil water retention characteristic curve and growth indices of *Ligustrum ovalifolium* (an ornamental plant that dominates the landscape of central Iran). Hydrogels (Suprab A200) in various quantities were introduced to soil samples with varying percentages of water proportionate to potential evapotranspiration data. The data was statistically analyzed using a factorial experiment. Hydrogel caused the residual water content and saturated water content to rise, according to the results of the soil water retention model. The amount of available water grows to a maximum of nearly 2.3 times than control. The use of hydrogels can significantly reduce the amount of water that has to be irrigated, especially in coarse-textured soils. In arid and semi-arid parts of the world, this is a critical issue for improving the water management of coarse-textured soils.

Thomas (2008) conducted an experiment to check the survival of *Eucalyptus pilularis* and *E. citriodora* subsp. *variegata* seedlings by immersing the seedlings' root plug in a fully hydrated solution of hydro gel prior to planting. Five months after planting in the field hydro gel-treated seedlings had 12 and 5% death in *E. pilularis* and *C. citriodora* subsp. *variegata* seedlings compared to 26 and 14% death, respectively in control seedlings.

Oriquiriza *et al* (2009) implied that seedlings of *Eucalyptus grandis*, *Eucalyptus citriodora*, *Pinus caribaea*, *Araucaria cunninghamii*, *Melia volkensii*, *Grevillea robusta*, *Azadirachta indica*, *Maesopsis eminii* and *Terminalia superba* were studied for root and shoot biomass. Sand, sandy loam, loam, silt loam, and clay seedlings were potted in five different soil types. The seedlings' root and shoot growth responses were measured by measuring the dry weight of the roots, stems, leaves, and twigs, and they were cultivated under controlled circumstances in a greenhouse with amendments at two hydrogel levels: 0.2 and 0.4 percent w/w. After 8 weeks of normal watering, the addition of either 0.2 or 0.4 percent hydrogel to the five soil types resulted in a substantial increase in root dry weight ($p < 0.001$) in eight tree species compared to the controls. In addition, the dry weight of stems, leaves, and twigs in the nine tree species planted in hydrogel adjusted soil types was considerably ($p < 0.001$) greater than in the hydrogel free controls. These findings imply that adding a hydrogel to a soil improves the efficiency of water absorption and photosynthate usage in plants cultivated in soils with water content near to field capacity.

Ptach *et al* (2009) illustrated that the research analyzed the effects of hydrogel on seedlings. Hydrogel is a macromolecule substance that can efficiently bind water and absorb it. Under the case of poor soils, the ability of hydrogel to hold water is critical, especially while seedlings are developing in severe drought circumstances. From a theoretical standpoint, hydrogel and its good impact on seedling survival and growth are proven, but the issue remains as to how it can affect things like soil water potential, mycorrhizal reduction, and pollutant absorption. Agricultural, post-military, post-industrial, and post-drainage peat bogs were investigated as sites that are difficult to afforest. Under laboratory and greenhouse circumstances, the effect of hydrogel on soil moisture, pF curve, and seedling water consumption was also observed. The primary goal of this study is to determine the effects of hydrogel treatment on pine (*Pinus sylvestris*) seedling survival and growth processes.

Shao and Deng (2009) reiterated the impact of two kinds of hydrophilic polymers on drought and salt tolerance in 1-year-old *Populus deltoides* is 35–44 cuttings. Stockosorb 500 XL (Stockosorb) (a granular type, cross-linked poly potassium-co-(acrylic resin polymer)-co-polyacrylamide hydrogel) and Luquasorb1 product (a powder type of potassium polyacrylate) were used in the experiments, and both were manufactured by Stockhausen GmbH Krefeld and BASF Corporation in Germany. Drought or salt stress reduced leaf photosynthesis and transpiration, as well as plant water consumption and dry weight, considerably. Drought and/or salt stress treatments significantly reduced plant growth and leaf gas exchange in soils treated with 0.5 percent Stockosorb or Luquasorb, and stress-induced leaf damage was delayed for 31 and 51 days, respectively.

Agaba *et al* (2010) reiterated that the impact of introducing super absorbent polyacrylate (SAP) hydrogel to different soil types on plant available water (PAW),

evapotranspiration, and survival of *Eucalyptus grandis*, *Eucalyptus citriodora*, *Pinus caribaea*, *Araucaria cunninghamii*, *Melia volkensii*, *Grevillea robusta*, *Azadirachta indica*, *Maesopsis eminii*, and *Terminalia*. According to the findings, the 0.4 percent hydrogel amendment enhanced PAW by around three times in sand, two times in silt loam, and one fold in sandy loam, loam, and clay soils when respectively compared to the control. Alternative irrigations and draught conditions were treated to produce the tree seedlings, and the addition of either 0.2 or 0.4 percent hydrogel to the five soil types resulted in longer tree survival than the control.

Beniwal *et al* (2010) connoted that the the pre-dawn water potential, growth performance, and hydraulic architecture of well-irrigated and drought-stressed plants were studied to see if *Paxillus involutus* ectomycorrhizas (EM) and soil amendment with water-retaining polymers (hydrogel) could improve the performance of *Populus canescens*, a water-spending species. Regardless of the presence of hydrogel, *P. involutus* colonized roughly 75% of the roots of well-irrigated plants. Drought stress resulted in a ten percent reduction in EM. Plants that were not injected had just a little amount of EM colonisation (3 percent). Under drought stress, EM poplar in hydrogel enriched soil had the best pre-dawn water potential, the least biomass loss, and almost complete photosynthetic activity, and vice versa. In comparison to non-EM plants, EM plants had greater vessel cross-sectional areas and higher radial stem development.

Agaba *et al* (2011) summarized the effect of a hydrogel amendment to the top sand soil layer on water infiltration, irrigation frequency, water consumption efficiency, and biomass production of *Agrostis stolonifera* was studied. Data on irrigation frequency, water content in the bottom layer, water usage efficiency, and biomass production of *Agrostis stolonifera* were gathered, according to the methodology of the experiment. The lowest layer under the control bucket had more water content (10%) than the 0.2 percent or 0.4 percent hydrogel modified buckets. In comparison to the control, the hydrogel treated sand enhanced *Agrostis stolonifera* shoot and root biomass by 2.2 and 4 times, respectively. In comparison to the control, the 0.4 percent hydrogel amendment in sand boosted grass's water usage efficiency eightfold. The findings suggest that hydrogels can enhance sandy soil qualities for plant development by absorbing and holding water in the soil matrix for longer periods of time, hence lowering watering frequency.

Gilbert *et al* (2013) conducted a research study that laid out with and without hydrogels, seedlings of *Cajanus cajan* were grown in the nursery and in the field. Three replications were employed in the field, with three degrees of hydrogel concentration (7 g, 11 g, and 15 g). Seedlings were grown in soils that did not include hydrogels as a control. Root collar diameters and heights were measured in the nursery every two weeks for the first eight weeks. For the next three months, root collar diameters and heights were measured every

month. In addition, soil was taken from the base of each seedling at random once a month and evaluated for moisture using conventional laboratory protocols. An analysis of variance was performed on all of the data. The results demonstrate that at the three levels of hydrogels, the species' height and root collar diameter grew at considerably different rates. After transplanting, hydrogels raised soil moisture volume from 8.3 percent to 10% at the H15g level of hydrogels under *C. cajan*.

Lawrence *et al* (2013) studied the effect of cross-linked SAP hydro gel amendment on the performance of tree seedlings of *Picea abies*, *Pinus sylvestris* and *Fagus sylvatica* grown in temperate soils under water stress and non-water stress periods in a green house. The objective was to compare the root and shoot biomass of seedlings of the three species grown in sand, loam and clay soils amended with 0.4% w/w hydro gel in non-water stress conditions as well as survival, root and shoot biomass after subject to water stress. The seedlings were grown for 16 weeks, harvested and shoot as well as root biomass determined before water stress. The results showed that root and shoot biomass were generally higher in hydro gel amended soils compared to the controls. Root biomass was higher in hydro gel amended sandy soil compared to other soils.

Orikiriza *et al* (2013) illustrated that when SAP hydrogels are introduced into the soil, they absorb and retain water, assisting plant establishment. In a green house, the influence of a cross-linked SAP hydrogel amendment on the performance of *Picea abies*, *Pinus sylvestris*, and *Fagus sylvatica* tree seedlings cultivated in temperate soils under water stress and non-water stress periods were examined. The goal was to evaluate root and shoot biomass of seedlings of the three species cultivated in sand, loam, and clay soils modified with 0.4 percent w/w hydrogel under non-water stress conditions to survival, root, and shoot biomass following water stress. The results revealed that in hydrogel treated soils, root and shoot biomass was often higher than in control soils. Before water stress, *F. sylvatica* had lower root and shoot biomass than *P. abies* and *Pinus. sylvestris*. In the various soils investigated, the 0.4 percent hydrogel amendment dramatically boosted species survival.

Yang *et al* (2013) conducted an experiment to improve the utilization of water resources on rocky slopes by using super absorbent polymer (SAP) with the function of water retention. Super absorbent polymer in three levels, 0.15%, 0.3% and 0.45% were mixed with sandy loam soil. The saturated water content, evaporation rate and water holding capability of SAP treated soils were determined. The addition of SAP to the sandy loam soil resulted in a significant increase of the soil water retention compared to the controls. Also, the seed germination was significantly higher in SAP amended soil than in the soil without SAP. The 0.30% SAP treatment was the optimum selection for sandy loam soil improvement on steep rocky slopes.

Böhlenius and Overgaard (2014) conducted a research that stated the effects of direct

application of fertilizers and hydrogel on the establishment of Poplar Cuttings. Research was carried out at two agricultural locations, one with a loamy sand soil and the other with a silty loam soil. At the silty loam soil location, none of the treatments had an effect on survival or early growth, and the solid fertilizer slowed plant development. The solid fertilizer had a detrimental impact on both survival and early development in the loamy sand location. Early growth was also inhibited by hydrogel and the combination of hydrogel and solid fertilizer. Overall, treating poplar cuttings with hydrogel or fertilizers, either alone or in combination may not be an effective way to minimize poplar cutting mortality or improve early plant growth on agricultural land.

Felippe *et al* (2016) evaluated the effect of using the hydro gel in planting seedlings of *Eucalyptus benthamii* in pots and related to different water management. Seedlings about 25 cm planted in pots filled with 4.5 liter of soil were used. The experiment was conducted with absence and presence of hydro gel related to water management (irrigation only in the planting, every 3 and 6 days). Planting until the 47th day was evaluated for the symptoms of water stress, chlorophyll content and gas exchange. The hydro gel resulted in an increase in water retention, thus a delay in symptoms of water stress, positively influencing the chlorophyll content and gas exchange.

Chehab *et al* (2017) reviewed that Stockosorb® hydrogel was injected into the soil surrounding olive trees (TS) and compared to a control plot (TC) that did not receive any hydrogel treatment. Water content was usually greater in hydrogel treated soils than in control soils, according to the findings. In comparison to control trees, which were significantly stressed due to inadequate water status during the vegetative development and fruiting phase, the seasonal leaf patch output pressure (Pp) readings indicated that trees with Stockosorb® treatment had the greatest water status and were mildly stressed. Stockosorb® in the root zone of olive trees raised midday stomatal conductance (gs) and maximum quantum efficiency (Fv/Fm) considerably. The Stockosorb® addition to the soil greatly boosted shoot development, oil output, and rainfall usage efficiency, yet oil quality remained within the standards specified for a 'Extra virgin' certified olive oil.

Dehkordi (2017) evaluated the effect of the hydrophilic polymer (Super-AB-A-300) on salt and drought resistance in *Eucalyptus saligna* Sm. One-year-old cuttings of *E. saligna* were treated with salt (2 L of 300 mM NaCl), drought stress, and salt plus drought stress; an untreated set of cuttings was used as a control. All treatments were conducted with and without Super-AB-A-300 polymer in the soil mixture. The Super-AB-A-300 polymer held more water in the soil during water-deficit conditions and promoted tolerance to salinity and drought stresses in the *E. saligna* rooted cuttings. In addition, the Super-AB-A-300 polymer retained Cl⁻ and Na⁺ in the soil solution due to its high water-holding capability and the exchangeable K⁺ in the Super-AB-A-300 resulted in an amended K⁺ /Na⁺ balance in the salt-

treated plants. Furthermore, the Super-AB-A-300 polymer promoted greater resistance to salinity plus drought stresses, due to the salt- and water-holding capabilities of the polymer.

Filho *et al* (2018) reiterated that the focus of this research was to determine the best hydrogel dose for establishing seedlings of *Enterolobium contortisiliquum* (Vell.) Morong at two different luminosity levels for which seedlings were planted in pots using a subdivided plot design that included two degrees of luminosity in the plots, as well as full sun and 50% luminosity, and 10 doses of hydrogel in the sub-plots. The lowest ratios between height and stem diameter (8.50 and 8.68) were seen in seedlings grown in full light at dosages of 0 and 2 g hydrogel L⁻¹, respectively. The lowest ratio (8.14) was observed in shaded seedlings at a dosage of 3.0 g L⁻¹, although with a lower coefficient of determination. Under full sun, a dosage of 2 g L⁻¹ increased shoot dry weight; in shady circumstances, a dose of 3.5 g L⁻¹ enhanced shoot dry weight. Despite the fact that the species responded to the hydrogel dosages, the advantages of the polymer were not apparent under the conditions of the research.

Abdallah (2019) reported the impacts of hydro gel particles size on hydro gel's retained water availability (plant available water, PAW), daily water consumption (DWC) and survival of Guava seedlings subjected to drought. Moreover, some soil physical properties, i.e., WHC, water retention properties, and hydraulic conductivity (Ksat) were investigated. Hydrogel (Watersorb, "WS") application, particularly the WS of small particles, significantly reduced Ksat, and increased WHC and PAW. Therefore, seedlings grown in soil amended with fine (0.8–1.0mm), medium (1.0–2.0mm) and large (2–4mm) survived for 27.0±1.3, 24.0±1.1 and 17.0±0.7 days, respectively, compared to 13.0±1.0 days for the control. The water stored in the large particles was less readily available for plant roots.

Saoud *et al* (2020) conducted a research which stated that several experiments were conducted to see if using superabsorbent polymers, commonly known as hydrogels, may improve plant survival, growth, and water usage efficiency. In clay and sandy clay loam (SCL) soils, the influence of hydrogel application quantities and application techniques on plant survival and growth was examined. *Zea mays* and *Pinus pinea* were used as model plants in two pot studies. Banding or mixing was used to apply the hydrogel at different concentrations. Hydrogel banding at 0.4 percent in SCL boosts corn fresh and dry above-ground biomass by 25% and pine seedling survival time by 90%, according to the findings. Furthermore, hydrogel boosted SCL water retention by up to 33% at 100 kPa, but had no impact when applied to clay soils. As a result, the effectiveness of hydrogels in agriculture water saving is dependent on the application methods and volumes used.

Tomasková *et al* (2020) revealed that the purpose of this study was to see how hydrogel treatments (with sawdust, bio - fertilizers, compost, wheat straw, subsoil, or subsoil with a cobble layer) affected the survival, growth, and physiological features of 20 different tree

species after planting. The methodological interpretation relied that water control or incorporation of We administered water alone (control) or water with hydrogel and other materials to recently planted samplings in a semi-arid section of Iran in a field experiment (factorial design with seven treatments including a control, 20 species, and 10 repetitions). After 6 months, parameters such as tree height, health, osmotic potential, and biochemical qualities, as well as survival were measured which lead to implementation of hydrogel treatment considerably enhancing drought-sensitive species' performance. Thus, it can be concluded that hydrogel treatment has considerable advantages for drought-sensitive plants but none for drought-resistant species.

CHAPTER-III

MATERIALS AND METHODS

The present study entitled, "Response of *Melia dubia* and *Dalbergia sissoo* to sandy loam soil amended with water absorbent polymers" was carried out at main experimental area of the Department of Forestry & Natural Resources, Punjab Agricultural University (PAU), Ludhiana during the year 2021-22. Soil parameters were studied in Department of Soil Science at PAU Ludhiana. The experimental details and the methodology adopted for conducting the study is described in this chapter under following headings.

3.1 Name of Experiments

- A) Effects of water absorbing hydrogel on growth of *Melia dubia*
- B) Effects of water absorbing hydrogel on growth of *Dalbergia sissoo*

3.2 Weather and soil characteristics

At an altitude of 247 metres above mean sea level, Ludhiana is situated in India's subtropical area at 30°54'N latitude and 75°48'E longitude. The experimental location experiences frigid winters and hot, dry summers. 75% of the 760 mm of yearly rainfall, or 700 mm, falls between July and September. The various environmental parameters recorded from the weather station situated near to the experimental site is presented in Figure 3.1. The methodology adopted for the assessment of different soil parameters are given in the Table 3.1. The physicochemical parameters were measured at the beginning and end (i.e. 12 Map) of the experiment.

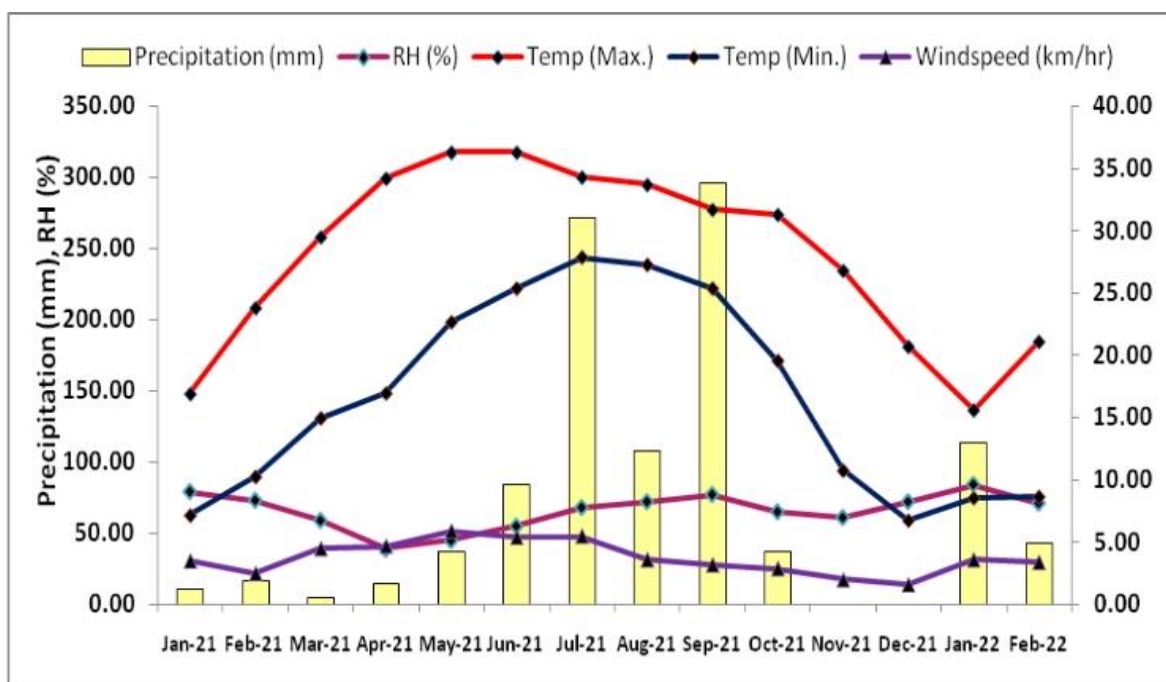


Figure 3.1: Mean monthly meteorological parameters of experimental site during 2021

Table 3.1: Physicochemical characteristics recorded of experimental site

Sr. No.	Characteristics	Method Employed
1.	Texture	International Pipette method (Piper 1966)
2.	pH (1:2 soil: water suspension)	Beckman's Glass electrode pH suspension) meter (Jackson 1967)
3.	Organic carbon (%)	Rapid Titration Method (wet Digestion) (Walkley and Black 1934)
4.	N (kg/acre)	Alkaline potassium permanganate method (Subbiah and Asija 1956)
5.	P (kg/acre)	Sodium Bicarbonate Extractable P (Olsen et al 1954)
6.	K (kg/acre)	N NH ₄ OAC Extractable K method (Merwin and Peech 1950)
7.	Electrical conductivity (mmhos/cm)	Solubridge Conductivity Meter (mmhos/cm at 250°C (Richard 1954)
8.	Zn (mg/kg soil)	DTPA method (Lindsay and Norvell (1978)
9.	Fe (mg/kg soil)	DTPA method (Lindsay and Norvell (1978)
10.	Mn (mg/kg soil)	DTPA method (Lindsay and Norvell (1978)
11.	Cu (mg/kg soil)	DTPA method (Lindsay and Norvell (1978)

3.3 Plant cultivation and experimental design

3.3.1 Treatments

The treatments consist of 7 levels of the hydrogel using the concentration 0, 25, 30, 35, 40, 45, 50 g/plant. Hydrogel was applied in the powdered form before planting the seedlings in pits size having 50×50×50 cm³ (1,25000 cm³) volume.

3.3.2 Experimental details

The seedlings were transplanted in the field in the month of February using a completely randomized block design at a spacing of 2×2 m with 8 plants per treatment and four replications.

3.4 Growth and Biomass characteristics

To study the effect of hydrogel application on the growth and biomass of *Melia Dubia* and *Dalbergia Sissoo*, the data on following parameters were same for both tree species collected and presented herewith:

3.4.1 Plant height

With the use of a metre rod, plant height was measured in metres from the ground to the tip of the highest point of shoot and recorded every 6 months interval between the start and end of the experiment.

3.4.2 Collar diameter

A vernier calliper was used to measure the collar's diameter in millimetres. The collar diameter measurements were gathered during a 6 months interval.

3.4.3 CAI for height

The current annual increment (CAI) for height was calculated by differencing the sapling height of one-year growth and seedling height at the time of plantation.

3.4.4 CAI for diameter

The CAI for diameter was computed similarly to the CAI for height by comparing the seedling collar diameter at planting time to the sapling collar diameter after one year of development.

3.4.5 Crown height

Crown height was measured in meters with the help of meter rod from ground level to the first branch of tree recorded in the end of experiment.

3.4.6 Crown length

Crown length was measured in meters with the help of meter rod from first branch of tree to the tip of the shoot recorded in the end of experiment or differencing the plant height and crown height.

3.4.7 Root length

Root length was measured in centimeters from collar region to the tip of longest root after uprooting at 12-month growth.

3.4.8 Plant fresh weight

The fresh weight of shoot root portion was measured in kilograms immediately after harvesting of plants on battery operated digital balance.

3.4.9 Plant dry weight

The uprooted plants were first dried in the sunlight for 15 days followed by in hot air oven till get the constant weight was recorded in kilograms.

3.5 Elemental concentration in leaves

Samples taken at 6 month after planting (MAP) and at the end of experiment were used for elemental analysis. The elements concentrations were estimated using recently matured 5th or 6th leave. In order to determine the amounts of nitrogen, phosphorus, and potassium, oven dried samples were crushed to a 32 mesh size.

3.5.1 Nitrogen

Content of nitrogen element was determined by drying the samples in hot air oven at 60 °C temperature till a constant weight. For determining nitrogen content, samples (0.5 g each) were digested using 10 ml of analytical grade concentrated H₂SO₄ along with a pinch of digestion mixture of K₂SO₄, CuSO₄, selenium powder and mercuric oxide (430:20:1:3). The digested material was made to 50 ml volume using distilled water and nitrogen content was

estimated by Kjeldahl's apparatus (Piper 1966).

3.5.2 Phosphorus

The estimation of phosphorus content in leaves was made using Vanado-Molybdo-Phosphoric yellow colour method in nitric acid system (Jackson 1967). Sample of 0.5 g was digested in triple acid mixture of HNO₃, HClO₄ and H₂SO₄ in ratio of 10:3:1, respectively. The intensity of colour was determined by spectronic-20 colorimeter at a wavelength of 470 µm using blue filter.

3.5.3 Potassium

Potassium content in dry leaves was estimated with the help of Lange's Flame photometer (Jackson 1967) from the extract prepared for phosphorus estimation.

3.6 Physiological characteristics

3.6.1 Chlorophyll contents

The chlorophyll content was estimated by taking 100 mg of leaves sample. The sample was finely chopped and homogenized using pestle and mortar, in 5 ml of acetone (80% solution). The homogenized mixture was centrifuged for 15 minutes at 10,000 rpm. 5 ml of acetone was added to supernatant. The absorbance was read at 645 and 663 nm wavelength on spectrophotometer. The following formulas were used to compute the Chl-a and Chl-b content (Anderson and Boardman 1964):

$$\text{Chl-a} = 12.25 (A_{663}) - 2.79 (A_{645}) \times V / (1000 \times W).$$

$$\text{Chl-b} = 21.50 (A_{645}) - 5.10 (A_{663}) \times V / (1000 \times W).$$

$$\text{Total chlorophyll} = 20.2(A_{645}) + 8.02(A_{663}) \times V / 1000 \times W.$$

Where, A₆₄₅ is absorbance at wavelength 645 nm

A₆₆₃ is absorbance at wavelength 663 nm

V is total volume of extract (ml)

W is weight of sample (mg)

3.6.2 Total carotenoid content

100 mg of leaves were weighed, then they were coarsely chopped and homogenised in 5 ml of acetone (an 80% solution) using a pestle and mortar. At 10,000 rpm, the homogenised mixture was centrifuged for 15 minutes. The supernatant was mixed with 5 cc of acetone. On a spectrophotometer, the absorbance was measured at wavelengths of 470, 645, and 663 nm. The carotenoid content was calculated using following formulas (Anderson and Boardman 1964):

$$\text{Carotenoid content} = 1000(A_{470}) - 1.82 \text{ Chl-a} - 85.02 \text{ Chl-b} \times V / (1000 \times W)$$

Where, A₄₇₀ is absorbance at wavelength 470 nm

V is total volume of extract (ml)

W is weight of sample (mg)

3.6.3. Relative Water Content

The relative water content (RWC) of 100 mg of leaves from all replications of all treatments was determined. After detaching from the plant, the sample was immersed in distilled water in a pre-weighed test container. By weighing the tubes again, the increase in weight of the test tubes was utilized to calculate the fresh weight (FW) of tissue. After 28 hours, the soaked tissue was weighed again to determine its turgid weight (TW). It was then dried in the oven for 48 hours at 70°C. The RWC was calculated as follows (Weatherly 1950):

$$\text{RWC} = \left(\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Saturated weight} - \text{Dry weight}} \right) \times 100$$

Where, FW is fresh weight, TW is turgid weight of tissue and DW is the dry weight of tissue.

3.6.4 Membrane Stability Index

In order to determine the membrane stability index (MSI), 100 mg of leaves from the replications of each treatment were used. The leaves were divided and washed with deionized water to get rid of the electrolytes released from the cut ends and those on the surface tissue. A conductivity metre was used to measure electrolyte leakage as each sample was incubated for 30 minutes at 25°C in 25 ml of deionized water. The sample was heated for 30 minutes before the conductivity was once more measured. The following formula was used to measure MSI (%) (Premchandra *et al* 1990):

$$\text{MSI} = (1 - C_1/C_2) \times 100$$

Where, C_1 is conductivity before boiling and C_2 after boiling

3.6.5 Total Soluble Sugars

(A) Reagents

- (a) 0.80% ethanol.
- (b) Concentrated H_2SO_4 (chilled)
- (c) 0.5% phenol

(B) Extraction

A 100 ml flask containing a 100 mg sample of fresh leaves was filled with deionized water for cleaning. The sugars were first extracted three times in 80% ethanol after being extracted twice in 80% ethanol over a hot water bath. Each time, the samples were boiled for 20 minutes. After being centrifuged at 5000 rpm for 5 minutes, the extracts were combined. After the pooled extracts were concentrated, the aqueous extracts were adjusted to a final volume of 10ml. To remove extra lead ions, 0.2 ml of lead acetate was injected into this sample, followed by a little amount of sodium oxalate. This extract was filtered and supernatant was used for estimation of total soluble sugars (Dubois *et al* 1956).

(C) Estimation

0.9ml of distilled water and 0.1ml of sugar extract were combined in a test tube. This was mixed with around 1ml of phenol solution (5%) in total. To ensure that the solution was well mixed, 5ml of cold, concentrated H₂SO₄ was poured into the centre of each tube after 5 minutes. The tubes were cooled to room temperature by flowing water. After 20 minutes, the orange-brown color's absorbance at 490 nm was measured in a spectrophotometer in comparison to a blank. Approximately 1 ml of phenol solution (5%), 1 ml of distilled water, and 5 ml of cold, concentrated H₂SO₄ were combined. The total soluble sugar concentration was estimated using a standard curve made with glucose standards (10-100g) and reported as mg g⁻¹ FW.

$$TPC = \frac{\text{Concentration of standard} \times \text{OD of test sample} \times \text{Total volume of extract}}{\text{OD of standard} \times \text{Volume of sample taken from extract} \times \text{Amount of tissue taken for extraction}}$$

3.7 Statistical analysis

The mean data collected on various growth and biomass parameters were statistically analysed using the Complete Randomized Block Design approach (CRBD) while leaf elemental concentration and physiological traits were analysed using CRD.

3.7.1 Analysis of Variance (ANOVA)

The experimental data were analyzed using analysis of variance technique (Panse and Sukhatme 1989). The various data were statistically analyzed using SPSS software. The significance of treatment effects was judged with the help of 'F' test (Variance ratio).

3.7.2 Genetic variability studies

3.7.2.1 Coefficients of variability

Genotypic and phenotypic variance was estimated as per the method described by Johnson *et al* (1955). Coefficients of variability was calculated by the formula suggested by Burton and De-vane (1953).

$$PCV \% = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

$$GCV \% = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

Where,

V_p = Phenotypic variance

V_g = Genotypic variance

PCV = Phenotypic Coefficient of Variability

GCV = Genotypic Coefficient of Variability

\bar{X} = Population mean

3.7.2.2 Heritability

Burton and De-vane (1953) and Johnson *et al.* (1953) proposed a formula for

calculating heritability in a restricted sense (1955).

$$h^2 = \frac{V_g}{V_p} \times 100$$

Where,

H^2 = Broad sense heritability.

3.7.2.3 Genetic advance

The genetic advance was calculated using Lush's (1940) formula, which was then utilised by Burton and De-Vane (1953) and Johnson et al (1955).

Genetic advance (GA). = $h^2 * \sigma_p * K$

$$\text{Genetic advance } (GA) = \left[\frac{V_g}{V_p} \right] * \sigma_p * K$$

Where,

V_g = Genotypic variance

V_p = Phenotypic variance

σ_p = Phenotypic standard deviation

K = Selection differential at 5 % selection intensity [$K = 2.06$].

3.7.2.4 Genetic gain.

Genetic gain was calculated by formula suggested by Johnson *et al* (1955) as under:

$$\text{Genetic gain} = \frac{\text{Genetic advance}}{\text{Population mean}} \times 100$$

3.7.2.4 Correlation analysis

Correlation coefficients were calculated according to the methods suggested by Goulden (1952). Correlation parameters and path analysis parameters were statistically analyzed using SPSS software. The simple correlation coefficients (Pearson 1901) were worked out by using the following formula (Panse and Sukhatme 1989).

$$r(XY) = \frac{\text{Cov,XY}}{\sqrt{V(x), V(y)}} \times 100$$

Where,

$r(XY)$ = Simple correlation Between X and Y.

$V(X)$ = Variance of X character.

$V(Y)$ = Variance of Y character.

CHAPTER-IV

RESULTS AND DISCUSSION

The present study entitled "Response of *Melia dubia* and *Dalbergia sissoo* to sandy loam soil amended with water absorbant polymers" was carried out at main experimental area of Department of Forestry & Natural Resources at Punjab Agricultural University, Ludhiana during the year 2021-22. The results obtained along with their discussion are presented under the following heads:

- 4.1 Effects of water absorbing polymer hydrogel on growth of *Melia dubia*
- 4.2 Effects of water absorbing polymer hydrogel on growth of *Dalbergia sissoo*
- 4.3 Physicochemical properties of soil
- 4.4 Genetic variability studies
- 4.5 Correlation studies

4.1 Effects of water absorbing polymer hydrogel on growth of *Melia dubia*

4.1.1 Growth and biomass characteristics

4.1.1.1 Plant height

The significant differences were observed for the sapling height (m) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Depiction of difference in values of plant height is presented in Table 4.1. The seedling height procured from the Genetics and Tree Propagation Division, Forest Research Institute, Dehradun was almost same with the mean height of 0.34 ± 0.03 m at the time of planting in field since February 2021. Significantly maximum plant height (2.48 ± 0.14 m) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in plant height as the hydrogel concentration is increased at 6 months after planting (MAP). However, the minimum sapling height (1.52 ± 0.04 m) was observed for control. All treatments of hydrogel are desirable as it showed high response and recorded improved height growth than control. Similar trend for sapling was recorded at 12 MAP. The maximum height (3.99 ± 0.23 m) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in sapling height as the hydrogel concentration was increased. However, the minimum sapling height (2.26 ± 0.04 m) was observed for control. The results are presented in this study are similar with the findings of Pattanaik *et al* (2015) who studied the effect of hydrogel in *Citrus limon* that showed the significant increase in the plant height than control.

4.1.1.2 Collar diameter

The significant differences were observed for the collar diameter (mm) of saplings of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Table 4.1 illustrate the difference in collar diameter. The seedling diameter was almost same with average collar diameter of 5.09 ± 0.56 mm at the planting time.

Significantly maximum sapling collar diameter (38.39 ± 2.72 mm) was recorded in treatment T2 (30 gm/pit) followed by continuous reduction in sapling diameter as the concentration is increased at 6 MAP. However, the minimum sapling diameter (24.05 ± 0.74 mm) was observed for control. All treatments of hydrogel are desirable as it showed high response and recorded more diameter than control. Similar trend for sapling was recorded after 12 month of planting. The maximum diameter (61.82 ± 4.32 mm) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in sapling diameter as the concentration is increased. However, the minimum sapling diameter (32.77 ± 1.03 mm) was observed for control. The results with respect to collar diameter finds support from the report of Kargar *et al* (2017) who reported that the significant increase was recorded in collar diameter due to hydrogel application in root zone of *Ulmus pumila* and *Acer saccharinum*.

4.1.1.3 CAI for height

The significant differences were observed for the current annual increment (CAI) for plant height (m) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel. The Table 4.1 depicts the values for CAI for plant height. The seedling height was almost same at the time of planting in field. Significantly maximum CAI for plant height (3.65 ± 0.21 m) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in increment of sapling height as the concentration was increased. However, the minimum increment of sapling height (1.90 ± 0.30 m) was observed for control. All treatments of hydrogel are desirable as it showed high response and recorded more increment than control.

4.1.1.4 CAI for collar diameter

The significant differences were observed for the CAI for collar diameter (mm) of saplings of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Table 4.1 represents the respective values for CAI for collar diameter. The seedling diameter was almost same at the time of planting in field. The mean CAI for collar diameter was 38.60 ± 5.05 mm. Significant maximum CAI for sapling in diameter (56.54 ± 3.97 mm) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in increment of sapling diameter as the concentration was increased. However, the minimum increment of sapling in diameter (27.49 ± 8.54 mm) was observed for control.

4.1.1.5 Crown height

The crown height of *M. dubia* sapling was measured from the collar diameter to the first crown forming branch or starting point of flush green foliage. The significant differences were observed for the sapling crown height (m) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations (Table 4.2). Significantly maximum sapling crown height (2.38 ± 0.13 m) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in sapling crown height as the concentration was increased at 12 MAP with an average crown height of 1.83 ± 0.15 m. Whereas, the minimum crown height

(1.43±0.11 m) was observed in control.

4.1.1.6 Crown length

Crown length was measured by the differencing of total plant height and crown height as presented in Table 4.2. The significant differences were observed for the crown length (m) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel. Sapling crown length was ranged from 0.83 to 1.61 m. Significantly maximum sapling crown length (1.61±0.10 m) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in sapling crown length as the concentration was increased at 12 MAP. However, the minimum sapling crown length (0.83±0.08 m) was observed for control. All the treatments of hydrogel concentration are desirable as it showed high response and recorded more crown length than control.

4.1.1.7 Root length

The significant differences were observed for the root length (cm) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Table 4.2 summarizes the values of mean root length of all replicated plants. Significantly maximum sapling root length (142.00±10.05 cm) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in sapling root length at 12 MAP as the concentration was increased. However, the minimum sapling root length (78.70±6.70 cm) was observed for control which was almost ~45.21% less than the T2 treatment. All treatments of hydrogel are desirable as it showed high response and recorded more root length than control (78.70±6.70 cm). These results are in line with the findings of Chen *et al* (2003) who reported that hydrogel treated plants had approximately 3.5 times higher root length than control in *Populus euphratica*. Mazen *et al* (2015) also reported the same results in maize plants where excessive root formation was induced by application of hydrogels.

4.1.1.8 Plant fresh weight

Total plant fresh weight includes the sum of root and shoots weight. For this purpose, main tap root including major secondary roots were dig up from the field and chopped into small pieces for measuring the total plant fresh weight. The significant differences were observed for the plant fresh weight (kg) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Values of plant fresh weight are depicted in Table 4.2. Significantly maximum plant fresh weight (31.25±3.09 kg) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in plant fresh weight at 12 MAP as the concentration was increased. The mean minimum plant fresh weight (14.40±1.44 kg) was recorded for control. All treatments of hydrogel are desirable as it showed high response and recorded more fresh weight than control.

Table 4.1: Response of growth and increment of *Melia dubia* saplings for varying levels of hydrogel application in soil

Treatment	Plant height (m)			Collar diameter (mm)			Current Annual Increment	
	0 MAP	6 MAP	12 MAP	0 MAP	6 MAP	12 MAP	Height (m)	Diameter (mm)
T0	0.36±0.04	1.52±0.04	2.26±0.20	5.28±1.05	24.05±0.74	32.77±1.03	1.90±0.30	27.49±8.54
T1	0.36±0.03	2.20±0.21	3.28±0.33	5.47±0.32	31.72±3.75	47.80±7.86	2.92±0.30	42.33±7.56
T2	0.34±0.02	2.48±0.14	3.99±0.23	5.28±0.39	38.39±2.72	61.82±4.32	3.65±0.21	56.54±3.97
T3	0.33±0.02	2.19±0.24	3.07±0.33	4.91±0.53	30.00±3.43	45.79±4.91	2.74±0.31	40.88±4.61
T4	0.35±0.02	2.00±0.24	3.05±0.34	4.72±0.55	29.66±6.42	45.01±9.50	2.70±0.14	40.29±3.87
T5	0.34±0.03	1.75±0.11	2.60±0.16	5.00±0.27	25.53±2.95	37.76±4.32	2.26±0.21	32.76±1.23
T6	0.33±0.01	1.70±0.15	2.46±0.23	5.00±0.22	24.40±0.89	34.90±1.12	2.13±0.19	29.90±0.82
Mean±SEm	0.34±0.03	1.98±0.18	2.96±0.27	5.09±0.56	29.11±3.43	43.69±5.47	2.61±0.24	38.60±5.05
Range	0.33-0.36	1.52-2.48	2.26-3.99	4.72-5.47	24.05-38.39	32.77-61.82	1.90-3.65	27.49-56.54
CD _{0.05}	0.11	0.14	0.18	0.37	1.96	4.08	0.24	3.65

4.1.1.9 Plant dry weight

One kilogram mixture from green biomass sample was taken and kept for 15 days in sunlight and then transfer this sample in oven for drying purposes. It was replicated thrice. Once the drying process was completed, then the dry weight of this sample was taken and mean of this measured dry weight was expressed in grams. Total dry biomass of plant was calculated by multiplying dry weight of sample with the total green biomass. The significant differences were observed for the plant dry weight (kg) of *Melia dubia* plants grown in sandy loam soil amended with hydrogel at varying concentrations. Table 4.2 exhibits the values of plant dry weight. Significantly maximum plant dry weight (15.25 ± 1.93 kg) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in plant fresh weight as the concentration was increased at 12 MAP. The minimum plant dry weight (8.87 ± 0.74 kg) was recorded for control. All treatments of hydrogel are desirable as it showed high response and recorded more plant dry weight than control.

Similar observations have been recorded for plant fresh and dry weight earlier by Orikiriza *et al* (2009) that showed the significant increase in plant fresh and dry biomass at various concentrations of hydrogel then control in nine tree species i.e., *Eucalyptus grandis*, *Eucalyptus citriodora*, *Pinus caribaea*, *Araucaria cunninghamii*, *Melia volkensii*, *Grevillea robusta*, *Azadirachta indica*, *Maesopsis eminii*, *Terminalia superb* and observed that adding a hydrogel to a soil improves the efficiency of water absorption and photosynthate usage. Similar results were also reported by Wang and Boogher (1987) in *Chlorophytum comosum*.

Table 4.2: Response of growth and biomass of *Melia dubia* saplings for varying levels of hydrogel application in soil

Treatment	Crown height (m)	Crown length (m)	Root length (cm)	Plant fresh weight (kg)	Plant dry weight (kg)
T0	1.43±0.11	0.83±0.13	78.70±6.70	14.40±1.44	8.87±0.74
T1	2.02±0.19	1.26±0.14	101.45±3.20	17.65±1.30	9.40±0.66
T2	2.38±0.13	1.61±0.10	142.00±10.05	31.25±3.09	15.25±1.93
T3	1.90±0.18	1.17±0.16	109.75±10.20	22.80±2.60	11.50±1.50
T4	1.88±0.21	1.17±0.08	106.20±12.59	21.85±3.38	11.34±1.18
T5	1.64±0.08	0.96±0.10	88.25±11.86	20.58±0.97	10.73±1.89
T6	1.53±0.13	0.93±0.08	85.75±12.15	17.15±2.68	9.75±0.83
Mean±SEm	1.83±0.15	1.13±0.11	101.73±7.77	20.81±2.02	10.98±1.15
Range	1.43-2.38	0.83-1.61	78.70-142.00	14.40-31.25	8.87-15.25
CD _{0.05}	0.15	0.13	9.92	2.97	1.39

4.1.2 Elemental concentration in leaves

4.1.2.1 Leaf nitrogen

The recorded data for leaf nitrogen (%) of *Melia dubia* shown in Table 4.3 showed significant differences in nitrogen level at different concentrations of hydrogel applied into the soil once during the planting season. The maximum nitrogen percentage (2.52 ± 0.01 %) in rainy season was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in nitrogen percentage in leaves as the concentration of hydrogel was increased. However, the minimum leaf nitrogen (1.92 ± 0.11 %) was recorded for control in rainy season. Similar trend for leaf nitrogen was recorded in spring season. The maximum leaf nitrogen (2.28 ± 0.01 %) was recorded for treatment T2 (30 gm/pit), while, the minimum concentration of nitrogen (1.81 ± 0.01 %) in leaf was observed in control treatment.

4.1.2.2 Leaf phosphorus

The recorded data for leaf phosphorus (%) of *Melia dubia* shown in Table 4.3 showed significant differences in leaf phosphorus level at different concentrations of hydrogel. The values of leaf phosphorus are depicted by Table 4.3. The maximum phosphorus (0.20 ± 0.01 %) was recorded in the leaves of plants grown in treatment T2 (30 gm/pit). Interestingly, no trend was observed as the concentration of applied hydrogel was changed but observed higher phosphorus was recorded than control treatment. The minimum leaf phosphorus (0.12 ± 0.01 %) was recorded for control in rainy season. In spring season the maximum leaf phosphorus (0.18 ± 0.00 %) was recorded for treatment T3 (35 gm/pit). While, the minimum leaf phosphorus (0.12 ± 0.01 %) was observed for both treatments T6 (50 gm/pit) and control.

4.1.2.3 Leaf potassium

The recorded data for leaf potassium (%) of *Melia dubia* shown in Table 4.3 showed significant differences in leaf potassium level at different concentrations of hydrogel used in soil. In rainy season, the maximum potassium (1.81 ± 0.09 %) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in potassium percentage as the concentration of hydrogel was increased. However, the minimum leaf potassium (1.28 ± 0.08 %) was recorded for control. Similar trend for leaf potassium was recorded in spring season. In spring season the maximum leaf potassium (1.68 ± 0.15 %) was recorded for treatment T2 (30 gm/pit), whereas, the minimum (1.21 ± 0.04 %) was observed in control treatment.

The present results are in accordance with the study of Faried *et al* (2014) who clarified that the applications of hydrogel significantly increase the level of N, P, and K in plant leaves of *Solanum tuberosum*. These results are also supported by Bredenkamp (2000) who reported that hydrogel improves macro and micro nutrient uptake especially nitrogen, potassium and phosphorus.

Table 4.3: Response of elemental concentrations in leaves of *Melia dubia* saplings growth sandy loam soil amended with hydrogel

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	1.92±0.11	1.81±0.01	0.12±0.01	0.12±0.01	1.28±0.08	1.21±0.04
T1	2.04±0.01	2.08±0.01	0.18±0.01	0.14±0.01	1.72±0.14	1.25±0.10
T2	2.52±0.01	2.28±0.01	0.20±0.01	0.16±0.01	1.81±0.09	1.68±0.15
T3	2.24±0.01	2.12±0.01	0.17±0.01	0.18±0.00	1.65±0.17	1.58±0.07
T4	2.16±0.02	2.10±0.01	0.16±0.01	0.15±0.00	1.59±0.11	1.50±0.20
T5	2.12±0.01	2.08±0.01	0.17±0.01	0.13±0.02	1.55±0.13	1.47±0.25
T6	2.08±0.01	1.92±0.01	0.16±0.01	0.12±0.01	1.52±0.18	1.44±0.09
Mean±SEm	2.15±0.04	2.06±0.01	0.17±0.01	0.14±0.01	1.59±0.12	1.45±0.14
Range	1.92-2.52	1.81-2.28	0.12-0.20	0.12-0.18	1.28-1.81	1.21-1.68
CD _{0.05}	0.12	0.09	0.04	0.03	0.16	0.17

4.1.3 Physiological parameters

4.1.3.1 Chlorophyll-a

The recorded data for leaf chlorophyll-a (mg/g) of *Melia dubia* presented in Table 4.4 showed significant differences in leaf chlorophyll-a in the plants grown in sandy loam soil amended with different concentrations of hydrogel. The maximum chlorophyll-a (9.83±0.38 mg/g) was recorded for treatment T6 (50 gm/pit) which is reducing continuously as the concentration of hydrogel decreased and the minimum chlorophyll-a (5.12±0.26 mg/g) was recorded for control in rainy season. Similar trend is followed in spring season as the maximum chlorophyll-a (15.14±0.35 mg/g) was recorded for treatment T6 (50 gm/pit) and the minimum (8.11±0.20 mg/g) was in control treatment.

4.1.3.2 Chlorophyll-b

The recorded data for leaf chlorophyll-b (mg/g) of *Melia dubia* provided in Table 4.4 showed significant differences in leaf chlorophyll-b concentration. The maximum chlorophyll-b (2.82±0.14 mg/g) was recorded in leaves of plants grown in treatment T6 (50 gm/pit) which was reducing continuously as the concentration of hydrogel decreased. The minimum chlorophyll-b (0.72±0.02 mg/g) was recorded for control in rainy season. Same trend was followed in spring season as the maximum chlorophyll-b (5.36±0.18 mg/g) was recorded for treatment T6 (50 gm/pit) and the minimum chlorophyll-b (1.64±0.18 mg/g) was

observed for control.

4.1.3.3 Total chlorophyll

Total chlorophyll was calculated by the summation of chlorophyll-a and chlorophyll-b. The recorded data for total chlorophyll (mg/g) in leaf of *Melia dubia* showed significant differences in leaf total chlorophyll level at different concentrations of hydrogel (Table 4.4). The maximum total chlorophyll (12.65 ± 0.49 mg/g) was recorded for treatment T6 (50 gm/pit) which is reducing continuously as the concentration of hydrogel decreased. The minimum total chlorophyll (5.84 ± 0.57 mg/g) was recorded for control in rainy season. Similar trend was observed in spring season as the maximum total chlorophyll (20.50 ± 0.90 mg/g) was recorded for treatment T6 (50 gm/pit) and the minimum total chlorophyll (11.91 ± 0.23 mg/g) was observed for control treatment.

4.1.3.4 Total carotenoids

The data recorded for total carotenoid (mg/100g) of leaf of *Melia dubia* plants grown in soil amended with varying level of hydrogel does not show significant differences but recorded higher in plants grown in hydrogel amended soils than control treatment. Table 4.4 summarizes the values of total carotenoids. The maximum carotenoid content (0.08 ± 0.02 mg/100g) was recorded for treatment T6 (50 gm/pit), T2 (30 gm/pit) and T1 (25 gm/pit), respectively which were statistically at par with the remaining treatments including control as well. The minimum carotenoid content (0.05 ± 0.01 mg/100g) was recorded for control in rainy season. Similar results were recorded in spring season. The maximum (0.09 ± 0.02 mg/100 gm) was recorded for treatment T2 (25 gm/pit) and T3 (30 gm/pit) both and the minimum (0.06 ± 0.01 mg/100 gm) was in control.

Similar results were reported by Chandravanshi *et al* (2020) who revealed that treatment with application of recommended dose of fertilizers along with hydrogel recorded significantly higher chlorophyll-a, chlorophyll-b and total chlorophyll content in *Arachis hypogaea*. Besharati *et al* (2021) also reported the significant increase in chlorophyll content in *Hibiscus sabdariffa* with the application of hydrogel at varying combination in soil. Sayed *et al* (1991) studied the use of hydrogel polymer mixture (25:75, v:v) with added Hoagland nutrient solution in crops (*Lycopersicon esculentum*, lettuce *Lactuca sativa* and *Cucumis sativus*) and found that use of hydrogel polymer in saline conditions prevented the decrease of carotenoids in crops. Youssef (2002) reported the highest concentrations of (chlorophyll-a, chlorophyll-B and carotenoids) were found in tissues of plants treated with 1.0 percent or 0.5 percent nutrient-free hydrogels.

4.1.3.5 Relative water content

The recorded data for relative water content (RWC, %) in the leaves of *Melia dubia* plants showed significant levels (Table 4.5). The maximum relative water content (57.54 ± 2.78 %) was recorded for treatment T2 (30 gm/pit). However, the minimum relative

water content (40.85 ± 3.40 %) was recorded for control in rainy season. Similarly, in spring season, the maximum relative water content (75.16 ± 1.86 %) was observed in treatment T2 (30 gm/pit) same as in the rainy season and the minimum (61.64 ± 1.36 %) was in control treatment. In the study conducted by Ferreira *et al* (2014) in tangerine and orange cultivars application of hydrogel lessen the negative effects of water deficit and stabilized RWC by modifying stomatal exchange of gases. However, our results are in contradiction with results of Nissi *et al* (2021) who used different soil conditioners in sweet orange (*Citrus sinensis*) tree and found that there is no significant difference between RWC of plants under different pusa hydrogel concentrations and control.

4.1.3.6 Membrane stability index

The recorded data for membrane stability index (MSI, %) for leaves of *Melia dubia* plants grown in hydrogel amended soils showed significant results. Table 4.5 summarizes the values of MSI. The mean maximum membrane stability index (74.62 ± 1.20 %) was observed in treatment T2 (30 gm/pit) which is reducing continuously as the concentration of hydrogel increased. The minimum membrane stability index (52.11 ± 2.84 %) was recorded for control in rainy season. Similar trend is followed in the spring season as maximum membrane stability index (79.81 ± 0.69 %) was recorded for treatment T2 (30g m/pit) and the minimum membrane stability index (64.17 ± 2.28 %) was observed for control. Singh *et al* (2019) used the hydrogel treatments capsicum crop under cold and water deficit soil conditions at ladakh and reported that hydrogel at rate of 15 and 20 kg/ha significantly improved the membrane stability index than control. Hajlaoiu *et al* (2009) did a study in maize crop and found a similar result for membrane stability index under water and salt stress.

4.1.3.7 Total soluble sugar

The recorded data for total soluble sugars (TSS, mg/g) in leaves of *Melia dubia* showed significant variations. Table 4.5 depicts the values of TSS. The maximum total soluble sugar (24.15 ± 1.01 mg/g) was recorded for treatment T1 (25 gm/pit) followed by continuous reduction in TSS as the concentration of hydrogel was increased and the minimum value for total soluble sugar (12.28 ± 1.40 mg/g) was recorded for treatment T6 (50 gm/pit) in rainy season. In the spring season pattern remain same as the maximum total soluble sugar (23.35 ± 1.00 mg/g) was recorded in treatment T1 (25gm/pit) and the minimum (14.34 ± 1.22 mg/g) was in treatment T6 (50 gm/pit) as same in the rainy season. The present results are in line with findings of El-Aziz *et al* (2022) who reported in tomato that the maximum total soluble sugars are observed in the leaves of those plants that were in deficit water conditions.

Table 4.4: Response of physiology in leaves of *Melia dubia* for varying levels of hydrogel application in soil

Treatment	Chlorophyll-a (mg/g)		Chlorophyll-b (mg/g)		Total chlorophyll (mg/g)		Total carotenoids (mg/100g)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	5.12±0.26	8.11±0.20	0.72±0.02	1.64±0.18	5.84±0.57	9.75±0.89	0.05±0.01	0.06±0.01
T1	6.19±0.23	8.57±0.29	1.13±0.02	2.30±0.06	7.32±0.34	10.87±0.23	0.08±0.02	0.08±0.01
T2	6.57±0.09	11.87±0.44	1.98±0.03	2.73±0.20	8.55±0.19	14.60±1.89	0.08±0.02	0.09±0.02
T3	6.93±0.33	12.62±0.82	2.00±0.26	3.19±0.16	8.93±1.17	15.81±1.43	0.06±0.01	0.09±0.02
T4	8.43±0.27	14.62±0.46	2.30±0.26	4.34±0.14	10.73±0.47	18.96±0.99	0.07±0.01	0.07±0.01
T5	8.69±0.31	15.00±0.45	2.69±0.15	4.98±0.26	11.38±0.53	19.98±0.75	0.06±0.02	0.07±0.02
T6	9.83±0.38	15.14±0.35	2.82±0.14	5.36±0.18	12.65±0.49	20.50±0.90	0.08±0.12	0.08±0.04
Mean±SEm	7.39±0.30	12.28±0.50	1.95±0.17	3.51±0.19	9.34±0.38	15.78±1.08	0.07±0.04	0.08±0.02
Range	5.12-9.83	8.11-15.14	0.72-2.82	1.64-5.36	5.84-12.65	9.75-20.50	0.05-0.08	0.06-0.09
CD _{0.05}	0.38	0.49	0.21	0.17	0.62	0.58	0.03	0.05

Table 4.5: Response of physiology in leaves of *Melia dubia* for varying levels of hydrogel application in soil

Treatment	RWC (%)		MSI (%)		TSS (mg/g)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	40.85±3.40	61.64±1.36	52.11±2.84	64.17±2.28	23.24±1.59	21.22±0.74
T1	52.00±1.22	68.49±1.51	60.79±0.91	69.38±1.88	24.15±1.01	23.35±1.00
T2	57.54±2.78	75.16±1.86	74.62±1.20	79.81±0.69	19.32±0.75	19.54±1.58
T3	55.24±1.90	73.11±2.12	72.54±1.84	73.29±1.19	17.23±1.33	18.11±1.30
T4	56.00±1.48	71.48±1.55	67.28±0.81	69.00±2.44	16.33±1.11	17.63±0.94
T5	54.78±1.10	72.23±1.86	66.16±1.48	68.66±1.85	16.22±1.49	16.23±1.52
T6	51.52±0.66	69.83±0.92	63.12±1.87	65.44±1.67	12.28±1.40	14.34±1.22
Mean±SEm	52.56±1.33	70.28±1.56	65.23±1.76	69.96±1.94	18.40±1.34	18.63±1.23
Range	40.85-57.54	61.64-75.16	52.11-74.62	64.17-79.81	12.28-24.15	14.34-23.35
CD _{0.05}	1.94	1.68	2.19	2.71	1.96	1.63

4.2 Effects of water absorbing polymer hydrogel on growth of *Dalbergia sissoo*

4.2.1 Growth and biomass characteristics

4.2.1.1 Plant height

Dalbergia sissoo is slow growing tree species and drought tolerant tree species. It was clear from the data presented in Table 4.6 that application of hydrogel at varying levels improved the growth but didn't show any definite pattern of growth with increasing concentrations of hydrogel. It was observed that maximum sapling height (2.39±0.22 m) of *Dalbergia sissoo* plants was recorded in treatment T3 (35 gm/pit) followed by continuous reduction in sapling height as the concentration is increased at 6 MAP and minimum sapling height (1.89±0.39 m) was observed for control. At 12 MAP pattern remained same as maximum sapling height (2.83±0.28 m) was observed again for treatment T3 (35 gm/pit). The mean minimum sapling height (2.38±0.31 m) was observed for control. The difference in height under various treatments was showing significant results at the end of experiment. Similar results were observed by Montesano *et al* (2015) during the experiment to study the use of biodegradable super absorbent hydrogel in the growing media in cucumber crop and reported significant increase in the plant height than the crop under control conditions.

4.2.1.2 Collar diameter

Respective values of collar diameter in *Dalbergia sissoo* saplings are shown in Table 4.6. The mean maximum sapling collar diameter (31.08±3.32 mm) in plants grown in sandy

loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35 gm/pit) followed by continuous reduction in sapling collar diameter as the concentration is increased at 6 MAP. The minimum sapling collar diameter (21.38 ± 3.41 m) was observed for control. At 12 MAP pattern remained same as maximum sapling collar diameter (38.35 ± 4.13 mm) was observed for treatment T3 (35 gm/pit) followed by continuous reduction in sapling collar diameter as the concentration was increased. The minimum sapling collar diameter (24.82 ± 4.28 mm) was observed for control. The huge growth in collar diameter was recorded in between 6 to 12 MAP than 0 to 6 MAP period. Similarly, Mews *et al* (2015) observed growth differences for the *Handroanthus ochraceus* plants to study the effects of hydrogel and different concentrations of urea. Chontal *et al* (2019) did study in maize crop and observed increase in plant diameter by use of hydrogel and fermented fertilizer.

4.2.1.3 CAI for plant height

It was observed during experiment that mean maximum increment for sapling height (2.38 ± 0.22 m) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35gm/pit) followed by continuous reduction in sapling CAI for height as the concentration was increased and minimum sapling CAI for height (1.90 ± 0.11 mm) was observed for control (Table 4.6). All treatments of hydrogel are desirable as it showed high response and recorded more increment than control.

4.2.1.4 CAI for collar diameter

Table 4.6 shows the depictive CAI values for collar diameter. The maximum CAI for sapling collar diameter (32.72 ± 0.07 mm) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35 gm/pit) followed by continuous reduction in sapling CAI for height as the concentration is increased and minimum sapling CAI for diameter (18.44 ± 0.03 mm) was observed for control (Table 4.6). All treatments of hydrogel are desirable as it showed high response and recorded more increment than control. The difference in CAI for collar diameter under various treatments was showing significant results at the end of experiment.

4.2.1.5 Crown height

The respective values of crown height measured from collar diameter to the first crown forming branch are presented in Table 4.7. It was observed that maximum sapling crown height (0.99 ± 0.09 m) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35gm/pit) followed by continuous reduction in sapling crown height as the concentration is increased. The minimum sapling crown height (0.85 ± 0.10 m) was observed for control. All treatments of hydrogel are desirable as it showed high response and recorded more crown height than control. The difference in crown height was showing significant results at the end of experiment.

Table 4.6: Response of growth of *Dalbergia sissoo* saplings for varying levels of hydrogel application in soil

Treatment	Plant height (m)			Collar diameter (mm)			Current Annual Increment	
	0 MAP	6 MAP	12 MAP	0 MAP	6 MAP	12 MAP	Height (m)	Diameter (mm)
T0	0.48±0.02	1.89±0.39	2.38±0.31	6.38±0.29	21.38±3.41	24.82±4.28	1.90±0.11	18.44±0.03
T1	0.62±0.08	2.15±0.09	2.56±0.12	8.00±0.44	27.11±1.47	36.13±2.49	1.94±0.09	28.13±0.16
T2	0.46±0.02	2.18±0.16	2.67±0.21	5.75±0.11	29.50±2.06	37.63±1.61	2.21±0.38	31.88±0.11
T3	0.45±0.03	2.39±0.22	2.83±0.28	5.63±0.33	31.08±3.32	38.35±4.13	2.38±0.22	32.72±0.07
T4	0.47±0.06	2.26±0.22	2.60±0.30	5.63±0.54	29.58±0.73	34.92±0.86	2.13±0.20	29.29±0.07
T5	0.49±0.04	2.20±0.24	2.54±0.25	5.66±0.34	25.03±1.19	29.41±1.75	2.05±0.20	23.75±0.12
T6	0.43±0.04	2.01±0.21	2.43±0.49	5.16±0.33	22.60±2.54	26.17±3.07	2.00±0.19	21.01±0.03
Mean±SEm	0.49±0.05	2.15±0.18	2.57±0.22	6.03±0.38	26.61±1.96	32.49±2.47	2.09±0.16	26.46±0.07
Range	0.43-0.62	1.89-2.39	2.38-2.83	5.16-8.00	21.38-31.08	24.82-38.35	1.90-2.38	18.44-32.72
CD _{0.05}	0.14	0.13	0.19	0.52	1.68	2.15	0.17	0.20

4.2.1.6 Crown length

Table 4.7 depicts the values of crown length which was measured by differencing total sapling height and crown height. It was observed during experiment that maximum sapling crown length (1.84 ± 0.19 m) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35gm/pit) followed by continuous reduction in sapling crown length as the concentration is increased and minimum sapling crown length (1.53 ± 0.09 m) was observed for control. All treatments containing varying levels of the hydrogel applied to the soil showed higher values of crown length than control treatment.

4.2.1.7 Root length

Table 4.7 shows the values recorded for root length. It was observed that maximum sapling root length (93.40 ± 9.41 m) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35 gm/pit) followed by continuous reduction in sapling root length as the concentration is increased. The minimum sapling root length (61.75 ± 4.94 m) was observed for control. All treatments of hydrogel are desirable as it showed high response and recorded more root length than control. The results are represented in this study are similar with the findings of Youssef (2002) in the plants of *Acacia melanoxylon* with the application of hydrogel. He found that all the concentrations of hydrogel in the peat moss growing media are able to significantly increase the length of root than control plants. Mazen *et al* (2015) also reported the maximum root length in the *Zea mays* plants grown in the media containing 0.4% hydrogel.

Table 4.7: Response of growth and biomass of *Dalbergia sissoo* saplings for varying levels of hydrogel application in soil

Treatment	Crown height (m)	Crown length (m)	Root length (cm)	Plant fresh weight (kg)	Plant dry weight (kg)
T0	0.85 ± 0.10	1.53 ± 0.09	61.75 ± 4.94	8.35 ± 0.89	4.60 ± 0.46
T1	0.92 ± 0.04	1.64 ± 0.15	64.80 ± 5.89	9.45 ± 1.01	5.30 ± 0.52
T2	0.95 ± 0.07	1.72 ± 0.32	72.30 ± 0.64	10.95 ± 0.32	6.00 ± 0.29
T3	0.99 ± 0.09	1.84 ± 0.19	93.40 ± 9.41	15.85 ± 1.59	8.55 ± 0.78
T4	0.93 ± 0.10	1.67 ± 0.20	69.20 ± 0.87	10.45 ± 0.38	5.80 ± 0.29
T5	0.92 ± 0.08	1.62 ± 0.21	62.65 ± 8.11	8.80 ± 1.33	5.00 ± 0.69
T6	0.87 ± 0.17	1.56 ± 0.17	62.75 ± 2.57	8.95 ± 0.95	4.85 ± 0.55
Mean \pm SEm	0.92 ± 0.07	1.65 ± 0.15	69.55 ± 5.62	10.40 ± 0.98	5.73 ± 0.53
Range	0.85-0.99	1.53-1.84	61.75-93.40	8.35-15.85	4.60-8.55
CD _{0.05}	0.11	0.14	6.57	1.90	1.05

4.2.1.8 Plant fresh and dry weight

Respective values of plant fresh and dry weight are presented in Table 4.7. It was observed during experiment that mean maximum plant fresh weight (15.85 ± 1.59 kg) of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel at varying concentrations was recorded in treatment T3 (35 gm/pit) followed by continuous reduction in plant fresh weight as the concentration was increased and minimum plant fresh weight (8.35 ± 0.89 kg) was recorded for control. The maximum plant dry weight (8.55 ± 0.78 kg) of *Dalbergia sissoo* plants was recorded again in treatment T3 (35 gm/pit) followed by continuous reduction in plant dry weight as the concentration is increased. The minimum plant dry weight (4.60 ± 0.46 kg) was recorded for control. Application of hydrogel treatment gave the better results than control treatment for fresh and dry biomass.

Similar results had been reported by Agaba *et al* (2011) for fresh and dry weight of *Agrostis stolonifera* during an experiment to study the effect of hydrogel under water deficit soil conditions. The use of hydrogel at 0.4% concentration found to increase the shoot and root biomass by 2.2 and 4.0 times more than the plants under control conditions. Orikiriza *et al* (2013) also observed that the use of hydrogel at 0.4% concentration gave maximum shoot and root biomass in *Pinus sylvestris* plants.

4.2.2 Elemental concentration in leaves

4.2.2.1 Leaf nitrogen

The recorded data for leaf nitrogen (%) of *Dalbergia sissoo* presented in Table 4.8 showed the significant differences. The maximum nitrogen percentage (2.24 ± 0.08 %) was recorded for treatment T4 (40 gm/pit) followed by continuous reduction in nitrogen percentage in leaves as the concentration of hydrogel is increased. However, the minimum leaf nitrogen (1.04 ± 0.19 %) was recorded for control in rainy season. Similar trend for leaf nitrogen was recorded in spring season. The maximum leaf nitrogen (2.68 ± 0.09 %) was recorded for treatment T4 (40 gm/pit) and the minimum leaf nitrogen (2.04 ± 0.08 %) was observed for control.

4.2.2.2 Leaf phosphorus

Table 4.8 depicts the values of leaf phosphorus. The recorded data for leaf phosphorus (%) of leaves of *Dalbergia sissoo* plants grown in hydrogel amended sandy lam soils does not showed any definite pattern but it is higher than control. The maximum phosphorus percentage (0.24 ± 0.02 %) was recorded for treatment T3 (35 gm/pit). However, the minimum leaf phosphorus (0.11 ± 0.02 %) was recorded for control in rainy season. In spring season the maximum leaf phosphorus (0.23 ± 0.03 %) was recorded for treatment T2 (30 gm/pit). Whereas, the minimum leaf phosphorus (0.13 ± 0.02 %) was observed for control.

4.2.2.3 Leaf potassium

The pertaining to data presented in Table 4.8 showed significant differences in leaf

potassium level in *Dalbergia sissoo* plants for both seasons. In rainy season, the maximum potassium percentage (1.02 ± 0.12 %) was recorded for treatment T3 (35 gm/pit) followed by continuous reduction in potassium percentage as the concentration of hydrogel was increased and more than the control treatment. The minimum leaf potassium (0.63 ± 0.04 %) was recorded for control. Similarly, the maximum leaf potassium (1.31 ± 0.07 %) was recorded for treatment T2 (30 gm/pit) followed by continuous reduction in percentage as the hydrogel concentration is increased in spring season, whereas, the minimum leaf potassium (0.61 ± 0.09 %) was observed for control.

Senna and Botaro (2017) did an experiment using different types of biodegradable hydrogel on the plants of eucalyptus and reported the maximum concentration nitrogen, phosphorus and potassium in the leaves of plants grown in the media containing NPK immersed hydrogel. These results are in line with our findings.

Table 4.8: Response of nutrients in leaves of *Dalbergia sissoo* saplings for varying levels of hydrogel in soil

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	1.04±0.19	2.04±0.08	0.11±0.02	0.13±0.02	0.63±0.04	0.61±0.09
T1	1.56±0.04	2.40±0.40	0.14±0.02	0.16±0.03	0.83±0.08	0.82±0.11
T2	1.98±0.14	2.40±0.13	0.20±0.02	0.23±0.03	0.95±0.09	1.31±0.07
T3	2.20±0.09	2.44±0.13	0.24±0.02	0.21±0.01	1.02±0.12	1.04±0.07
T4	2.24±0.08	2.68±0.09	0.19±0.04	0.18±0.01	0.99±0.02	0.94±0.07
T5	2.02±0.13	2.32±0.20	0.20±0.05	0.20±0.01	0.94±0.12	0.88±0.09
T6	1.68±0.03	2.08±0.07	0.17±0.02	0.16±0.03	0.78±0.09	0.86±0.06
Mean±SEm	1.82±0.10	2.34±0.20	0.18±0.03	0.18±0.03	0.88±0.09	0.92±0.09
Range	1.04-2.24	2.04-2.68	0.11-0.24	0.13-0.23	0.63-1.02	0.61-1.31
CD _{0.05}	0.09	0.11	0.06	0.08	0.15	0.11

4.2.3 Physiological parameters

4.2.3.1 Chlorophyll-a

The recorded data for leaf chlorophyll-a (mg/g) in *Dalbergia sissoo* plants showed significant differences (Table 4.9). The maximum chlorophyll-a (15.85 ± 0.48 mg/g) was recorded for treatment T2 (30 gm/pit) which is reducing continuously as the concentration of hydrogel is increased up to T5 (45 g/pit) and after that in treatment T6 (50 gm/pit) it again increases. The minimum chlorophyll-a (8.98 ± 0.26 mg/g) was recorded in control treatment in

rainy season. In spring season, the maximum chlorophyll-a (17.50 ± 0.85 mg/g) was recorded in T3 (35 gm/pit) which is reducing continuously as the hydrogel concentration increasing up to T5 (45 gm/pit) and after that in treatment T6 (50 gm/pit) it again increases. However, the minimum chlorophyll-a (9.21 ± 0.91 mg/g) was observed for control.

4.2.3.2 Chlorophyll b

The recorded data for chlorophyll-b (mg/g) in leaves of *Dalbergia sissoo* plants presented in Table 4.9 showed significant differences. The mean maximum chlorophyll-b (3.78 ± 0.17 mg/g) was recorded for treatment T2 (30 gm/pit) which is reducing continuously as the concentration of hydrogel is increased up to T5 (45 g/pit) and after that in treatment T6 (50 gm/pit) it again increases. All treatments showed significant higher values for chlorophyll-b than control treatment. The minimum chlorophyll-b (2.30 ± 0.06 mg/g) was recorded for control in rainy season. In spring season, the maximum chlorophyll-b (8.55 ± 0.15 mg/g) was recorded for treatment T3 (35 gm/pit) which is reducing as the hydrogel concentration increasing up to T5 (45 gm/pit) and after that in treatment T6 (50 gm/pit) it again increases. The minimum chlorophyll-b (6.12 ± 0.57 mg/g) was observed for control treatment.

4.2.3.3 Total chlorophyll

The recorded data for total chlorophyll (mg/g) of leaves of *Dalbergia sissoo* showed significant differences (Table 4.9). The maximum total chlorophyll (19.63 ± 1.90 mg/g) was recorded for treatment T2 (30 gm/pit) which is reducing as the concentration of hydrogel is increase up to T5 (45 g/pit) and after that in treatment T6 (50 gm/pit) it again increases. The minimum total chlorophyll (11.28 ± 0.66 mg/g) was recorded for control in rainy season. In spring season the maximum total chlorophyll (26.05 ± 0.75 mg/g) was recorded for treatment T3 (35gm/pit) which is reducing as the hydrogel concentration increasing up to T5 (45 gm/pit) and after that in treatment T6 (50 gm/pit) it again increases. The minimum total chlorophyll (15.33 ± 0.38 mg/g) was observed in control.

4.2.3.4 Total carotenoids

Total carotenoids content (mg/100g) in leaves of *Dalbergia sissoo* plants presented in Table 4.9 showed no definite pattern in the treatments of hydrogel applications. However, the maximum carotenoid content (0.05 ± 0.01 mg/100g) was recorded for treatment T3 (35 gm/pit) and T4 (40 gm/pit) and the minimum (0.02 ± 0.01 mg/100g) was recorded for control and treatment T6 (50 gm/pit) in rainy season. Similarly, for the spring season, the maximum carotenoid content (0.06 ± 0.02 mg/100 gm) was recorded for treatment T6 (50gm/pit) and the minimum (0.04 ± 0.01 & 0.04 ± 0.02 & 0.04 ± 0.01 mg/100 gm) was observed for control, treatment T4 (40 gm/pit) and T5 (45 gm/pit), respectively.

The results presented in this study are similar to the experiment conducted by the Jnanesha *et al* (2021) in which different concentrations of hydrogel are used in senna (*Cassia*

Table 4.9: Response of physiology in leaves of *Dalbergia sissoo* for varying levels of hydrogel application in soil

Treatment	Chlorophyll-a (mg/g)		Chlorophyll-b (mg/g)		Total chlorophyll (mg/g)		Total carotenoids (mg/100g)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	8.98±0.26	9.21±0.91	2.30±0.06	6.12±0.57	11.28±0.66	15.33±0.38	0.02±0.01	0.04±0.01
T1	10.88±0.64	11.98±0.32	2.80±0.17	7.40±0.31	13.68±0.43	19.38±1.74	0.03±0.02	0.05±0.01
T2	15.85±0.48	12.59±0.79	3.78±0.17	7.45±0.51	19.63±1.90	20.04±2.44	0.04±0.01	0.05±0.01
T3	15.29±1.60	17.50±0.85	2.83±0.07	8.55±0.15	18.12±0.19	26.05±0.75	0.05±0.01	0.05±0.01
T4	12.85±0.50	17.44±0.60	2.56±0.34	7.68±0.12	15.41±1.21	25.12±1.14	0.05±0.01	0.04±0.02
T5	10.13±0.56	10.36±0.61	2.61±0.53	6.25±0.02	12.74±1.33	16.61±0.56	0.03±0.01	0.04±0.01
T6	10.77±0.55	11.01±0.85	2.79±0.22	6.43±0.15	13.56±0.87	17.44±0.85	0.02±0.01	0.06±0.02
Mean±SEm	12.11±0.74	12.87±0.42	2.81±0.29	7.13±0.33	14.92±0.89	20.00±1.05	0.03±0.01	0.05±0.01
Range	8.98-15.85	9.21-17.50	2.30-3.78	6.12-8.55	11.28-19.63	15.33-26.05	0.02-0.05	0.04-0.06
CD _{0.05}	1.19	1.24	0.56	0.48	1.64	1.09	0.03	0.03

angustifolia) plants and found that the maximum chlorophyll content was observed in the treatment having hydrogel at the concentration of 3 kg/ha followed by the treatment having 2.5 kg/ha hydrogel. Youssef (2002) did an experiment on plants of *Acacia melanoxylon* using various concentrations of hydrogel in peat moss media and found that media containing 0.5 and 1.0% hydrogel has higher amounts of carotenoids than other treatments.

4.2.3.5 Relative water content

The relative water content (RWC, %) in the leaves of *Dalbergia sissoo* plants showed significant differences among the treatments applied than control. Table 4.10 depicts the values of RWC. The maximum relative water content (56.74 ± 0.61 %) was recorded for treatment T4 (40gm/pit) and the minimum (42.55 ± 1.16 %) was recorded for control in rainy season. In the spring season, the maximum relative water content (75.43 ± 1.35 %) was recorded for treatment T3 (35 gm/pit) and the minimum (62.26 ± 0.64 %) was observed for control treatment. The result with respect to relative water content (RWC) finds support from the report of Mbarki *et al* (2018) who found that percentage of RWC comparatively higher in plants of olive under hydrogel treatment than the plants are grown under control treatment.

Table 4.10: Response of physiology in leaves of *Dalbergia sissoo* for varying levels of hydrogel application in soil

Treatment	RWC (%)		MSI (%)		TSS (mg/g)	
	Rainy	Spring	Rainy	Spring	Rainy	Spring
T0	42.55±1.16	62.26±0.64	53.24±1.54	67.78±1.32	31.24±2.00	34.58±1.05
T1	51.89±1.80	71.58±1.04	54.15±1.44	77.12±1.75	36.32±0.88	37.12±1.33
T2	54.92±0.95	72.23±1.17	61.18±2.09	74.35±2.03	29.34±1.66	29.78±2.70
T3	53.44±2.69	75.43±1.35	62.56±1.64	80.92±1.90	27.32±0.39	30.24±1.73
T4	56.74±0.61	73.85±1.32	58.93±1.00	81.34±2.27	28.17±1.67	27.88±1.11
T5	44.22±1.04	70.12±0.75	55.12±1.39	72.93±2.31	24.56±1.74	25.67±1.05
T6	45.36±1.69	69.37±1.84	57.34±1.61	69.76±0.97	25.13±1.25	26.92±1.48
Mean±SEm	49.87±1.46	70.69±0.90	57.50±1.18	74.89±2.00	28.87±1.45	30.31±1.56
Range	42.55-56.74	62.26-75.43	53.24-62.56	67.58-81.34	24.56-36.32	25.67-37.12
CD _{0.05}	2.31	2.65	3.48	2.89	1.29	1.62

4.2.3.6 Membrane stability index

Respective values of MSI are presented in Table 4.10. The membrane stability index (MSI %) in leaves of *Dalbergia sissoo* plants showed significant results. The maximum membrane stability index (62.56 ± 1.64 %) was recorded for treatment T3 (35 gm/pit) which is

reduced as the concentration of hydrogel is increased up to T5 (45 g/pit) and after that in treatment T6 (50 gm/pit) it again increased. The minimum membrane stability index (53.24 ± 1.54 %) was recorded for control in rainy season. In the spring season maximum membrane stability index (81.34 ± 2.27 %) was recorded for treatment T4 (40 gm/pit) and the minimum membrane stability index (67.78 ± 1.32 %) was observed for control. Singh *et al* (2019) demonstrated that the use of hydrogel improved the membrane stability index in capsicum and results are in line with our findings. Gupta *et al* (2000) also observed improved membrane stability index in saline and water deficit soil condition in *Triticum aestivum*.

4.2.3.7 Total soluble sugars

The data pertaining total soluble sugars (TSS, mg/g) in leaves of *Dalbergia sissoo* plants grown in sandy loam soil amended with hydrogel application at varying concentrations showed significant differences. The maximum total soluble sugars (36.32 ± 0.88 mg/g) were recorded for treatment T1 (25 gm/pit) which is reduced as the concentration of hydrogel is increased up to T5 (45 g/pit) and after that in treatment T6 (50 gm/pit) it again increased. The minimum total soluble sugars (24.56 ± 1.74 mg/g) were recorded for treatment T5 (45 gm/pit) in rainy season. In the spring season, the maximum total soluble sugar (37.12 ± 1.33 mg/g) were recorded for treatment T1 (25 gm/pit) and the minimum total soluble sugars (25.67 ± 1.05 mg/g) were observed for treatment T5 (45 gm/pit) same as in the rainy season (Table 4.10). El-Aziz *et al* (2022) studied the efficacy of hydrogel to prevent the drought stress in tomato plants and found maximum TSS in plant leaves under control conditions.

4.3 Physicochemical properties of soil

Different physicochemical soil characteristics were recorded before the establishment of evaluation trial and at the end of experiment, i.e. 12 MAP (Table 4.11). The soil properties were recorded irrespective to tree species and hydrogel treatments. The soil samples were collected randomly from the different locations of field and mixed thoroughly, and then used for the analysis. There was a minor changes were recorded in all the soil parameters. The pH of soil is decreased mainly due to the process of decomposition which leads to production of different acids through decomposition of leaf litters and other organic matters. Organic carbon is increased because of continuous addition of organic matter and reduced disturbance in soil and availability of nitrogen is also increased due to increase in organic carbon. There is a little decrease in available phosphorus, small rise in available potassium and no change in electrical conductivity of soil is observed. Increase in availability of all four micro nutrients (Zn, Fe, Mn and Cu) was registered at end of experiment. It could mainly attribute to the rise of humus in soil which form complex with micro nutrients and increase their availability.

Table 4.11: Physiochemical characteristics of experimental site

Parameter	Test value at beginning of experiment	Test value at the end of experiment
Soil texture	Sandy loam	Sandy loam
Soil pH	8.30	8.10
OC (%)	0.308	0.382
N (Kg/acre)	116	122
P (kg/acre)	3.50	3.40
K (kg/acre)	132	136
EC (mmhos/cm)	0.10	0.10
Zn (mg/kg soil)	0.56	0.6
Fe (mg/kg soil)	8.46	9.98
Mn (mg/kg soil)	8.18	8.70
Cu (mg/kg soil)	0.54	0.59

4.4 Genetic variability studies

4.4.1 Genetic variability study of *Melia dubia*

Variability and genetic parameters estimated for growth, biomass, elemental concentration in leaves and physiology of leaves of *Melia dubia* plant in terms of average, range, genotypic phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic gain as percent of mean are presented in Table 4.12. All the studied parameters showed a broad range of values signifying the amount of variation presented in different parameters. Plant height, collar diameter, crown height, crown length, leaf potassium, plant fresh weight, plant dry weight, carotenoids and total soluble sugars (TSS) showed wide range of variability. Environmental factors has very less influence on root length, elemental concentration in leaves (N and P), chlorophyll-a, chlorophyll-b, total chlorophyll, , relative water content (RWC) and membrane stability index (MSI) because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes.

The very high heritability was recorded in root length, plant fresh and dry weight, leaf N, P, chlorophyll-a, chlorophyll-b, total chlorophyll, total carotenoids, RWC, MSI and TSS, while moderate was observed for crown length, leaf K in rainy season, plant height, and crown height. However, low was recorded for collar diameter and leaf K in spring season. This reflects that collar diameter and leaf K was not tightly linked with its genetic constitution and highly

Table 4.12: Variability estimates and genetic parameters in *Melia dubia*

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)	
			GCV (%)	PCV (%)				
PH	2.96	2.26-3.99	17.55	25.21	48.48	0.7	25.18	
CD	43.69	32.77-61.82	18.78	31.30	35.98	10.1	23.20	
CH	1.83	1.43-2.38	15.70	23.04	46.40	0.4	22.03	
CL	1.13	0.83-1.61	20.57	28.91	50.60	0.3	30.14	
RL	101.73	78.70-142.00	23.55	27.19	75.02	41.6	42.03	
LN	Rainy	2.15	1.92-2.52	35.16	35.17	99.94	1.9	72.41
	Spring	2.06	1.81-2.28	19.47	19.80	96.78	0.9	39.47
LP	Rainy	0.17	0.12-0.20	11.75	13.24	78.75	0.1	21.48
	Spring	0.14	0.12-0.18	14.14	16.34	74.89	0.1	25.21
LK	Rainy	1.59	1.28-1.81	18.63	25.68	52.64	0.4	27.85
	Spring	1.45	1.21-1.68	7.55	16.80	20.17	0.1	6.98
PFW		20.81	14.40-31.25	28.34	33.15	73.09	10.2	49.91
PDW		10.98	8.87-15.25	27.31	33.70	65.67	4.6	45.60
CHL-a	Rainy	7.39	5.12-9.83	21.86	22.94	90.80	3.2	42.91

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)	
			GCV (%)	PCV (%)				
	Spring	12.28	8.11-15.14	23.74	24.78	91.77	5.8	46.85
CHL-b	Rainy	1.95	0.72-2.82	38.83	41.78	86.36	1.4	74.33
	Spring	3.51	1.64-5.36	67.62	67.91	99.15	7.3	78.70
Total CHL	Rainy	9.34	5.84-12.65	24.44	25.27	93.55	5.0	48.70
	Spring	15.78	9.75-20.50	23.05	24.99	85.04	8.5	43.78
CRTD	Rainy	0.07	0.05-0.08	127.80	129.18	97.87	0.4	26.46
	Spring	0.08	0.06-0.09	147.69	155.74	89.93	0.4	28.52
RWC	Rainy	52.56	40.85-57.54	6.35	7.12	79.64	8.4	11.67
	Spring	70.28	61.64-75.16	5.99	7.00	73.22	7.9	10.56
MSI	Rainy	65.23	52.11-74.62	10.27	11.28	82.84	13.8	19.25
	Spring	69.96	64.17-79.81	8.75	9.78	80.00	11.2	16.13
TSS	Rainy	18.40	12.28-24.15	14.98	19.13	61.31	4.7	24.16
	Spring	18.63	14.34-23.35	13.81	17.42	62.89	4.5	22.57

Note: PH- Plant height; CD- Collar diameter; CAI- PH- Current annual increment of plant height; CAI-CD- Current annual increment collar diameter; CH- Crown height; CL- Crown length; RL- Root length; LN- Leaf nitrogen; LP- leaf phosphorus; LK- Leaf potassium; PFW- Plant fresh weight; PDW- plant dry weight; CHL-a - Chlorophyll-a; CHL-b - Chlorophyll-b; Total CHL- Total chlorophyll; CRTD – Carotenoids; RWC - Relative water content; MSI - Membrane stability index; TSS -Total soluble sugars.

affected with the environmental conditions. Majority of traits studied were found highly controlled by plant genotype due to having very high heritability. In the present study, genetic advance was found highest for root length (41.6 %) which was followed by MSI (13.8 % in rainy and 11.2 % in spring season), plant fresh weight (10.2 %) and collar diameter (10.1 %). The lowest value (0.1 %) of genetic advance was observed for leaf P and K (spring season) followed by crown height (0.4 %), leaf K (rainy season), total carotenoids (0.4 %). The maximum genetic gain (78.70 %) was registered for chlorophyll-b followed by 72.41% for leaf N (rainy season) and 49.91 % and 45.60% for plant fresh and dry biomass, respectively. Very high heritability coupled with high genetic advance as per cent of mean was observed for root length (75.02% with 41.60%) which indicated that the predominance of additive gene action in the expression of these characters.

4.4.2 Genetic variability study of *Dalbergia sissoo*

Variability and genetic parameters estimated for growth, biomass, elemental concentration in leaves and physiology of leaves of *Dalbergia sissoo* plant in terms of average, range, genotypic phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic gain as percent of mean are presented in Table 4.13. All the studied parameters showed a broad range of values signifying the amount of variation. Collar diameter and crown length showed wide range of variability. Environmental factors has very less influence on plant height, crown height, root length, elemental concentration in leaves (N, P and K), plant fresh weight, plant dry weight, chlorophyll-a, chlorophyll-b, total chlorophyll carotenoids, relative water content (RWC) and membrane stability index (MSI) and total soluble sugars (TSS) because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes.

The very high heritability was recorded in plant fresh and dry weight, leaf N and K for spring season, chlorophyll-a, chlorophyll-b, total chlorophyll, MSI, TSS and RWC (spring season), while moderate was observed for collar diameter, leaf P and K for spring season and RWC for rainy season. However, very low heritability was recorded for plant height, crown height and length, leaf N (spring season) , leaf P (rainy season) and total carotenoids. This reflects that these low heritable characters were not tightly linked with its genetic constitution and highly affected with the environmental conditions. Majority of traits studied were found highly controlled by plant genotype due to having very high heritability. In the present study, genetic advance was found high for root length (14.1 %) which was followed by MSI (14.0 % in rainy and 14.2 % in spring season) and RWC (10.4 %). The lowest value (0.1 %) of genetic advance was observed for plant height, crown height and length, leaf P, carotenoids followed by leaf K for spring season (0.2 %) and leaf N for spring season (0.3%). The maximum genetic gain (67.60 %) was registered for chlorophyll-a followed by 64.01% for leaf K (rainy

season), 57.23 % for leaf N for rainy season and 38.30% for plant fresh weight, respectively. Very high heritability coupled with high genetic advance as per cent of mean was observed for MSI (14.2% with 82.74%) which indicated that the predominance of additive gene action in the expression of these characters.

4.5 Correlation studies

4.5.1 Correlation study of *Melia dubia*

Correlation reveals the depth of intricacy and degree of inter-relationship that exists between distinct features. Because some characters are inextricably related to one another, understanding their relationships is crucial when choosing one or more characters. It serves as a suitable starting point for indirect selection, particularly for below-ground or biomass features that necessitate disruptive sampling. The amount of genetic gain acquired by indirect selection, *i.e.* correlated response, provides a better understanding of the degree and size of genetic association and should be given fair weightage in any tree improvement program's selection criteria. The correlations among growth, biomass, leaf elemental concentrations and physiological traits in all possible combinations are presented in Table 4.14. A significant positive correlation between all growth and biomass parameters is observed but only few physiological parameters showed significant positive relationship. Chl-a, Chl-b and total chlorophyll has non-significant negative relation with most of the growth and biomass parameters and few physiological parameters. Plant height showed strongest positive relation with crown height followed by CAI height, crown length, collar diameter, CAI diameter, root length, MSI, leaf nitrogen, plant fresh weight and plant dry weight. Collar diameter showed strongest positive relation with CAI diameter followed by crown length, CAI height, crown height, root length, nitrogen, MSI, plant fresh weight and plant dry weight. CAI height has strongest positive correlation with crown height and crown length followed by CAI diameter, root length, MSI, nitrogen, plant fresh weight and plant dry weight. CAI diameter strongest positive relation with crown length followed by crown height, root length, nitrogen, MSI, plant fresh weight and plant dry weight. Crown height has strongest positive relation with crown length succeeded by root length, MSI, nitrogen, plant fresh weight and plant dry weight. Crown length has strongest positive relation with root length followed by MSI, nitrogen, plant fresh weight and plant dry weight. Root length has strongest positive relation with MSI followed by plant fresh weight, plant dry weight and nitrogen. Plant fresh weight has strongest positive relation with plant dry weight followed by MSI, nitrogen and RWC. Plant dry weight has strongest positive relation with MSI followed by potassium, nitrogen and RWC. Nitrogen has strongest positive relation with MSI followed by RWC and potassium. Phosphorus has strongest positive relation with TSS followed by MSI. Potassium has strongest positive relation RWC followed by MSI. Chl-a has strongest positive relation with total chlorophyll followed by Chl-b. Chl-b has strongest positive relation with total

chlorophyll. Carotenoids have strongest positive relation with TSS followed by MSI. RWC has strongest positive relation with MSI. MSI has strongest positive relation with TSS. Chl-a has negative but non-significant correlation with plant height, CAI height, crown length, collar diameter, CAI diameter, crown height. Chl-b and total chlorophyll have negative but non-significant correlation with plant height, CAI height, crown length, collar diameter, CAI diameter, crown height, root length, phosphorus and MSI. TSS has negative but non-significant correlation with Chl-b.

4.5.2 Correlation study of *Dalbergia sissoo*

In the Table 4.15 significant positive relations between all growth and biomass parameters are observed but only few physiological parameters showed significant positive relationship. Plant height showed strongest positive relation with crown length followed by crown height, CAI diameter, plant dry weight, CAI height, plant fresh weight, Chl b, root length, collar diameter, RWC, total chlorophyll, MSI, phosphorus Chl-a. collar diameter showed strongest positive relation with CAI diameter followed by crown height, Chl b, crown length, MSI, RWC, nitrogen and total chlorophyll. CAI height showed strongest positive relation with crown length followed by plant dry weight, plant fresh weight, root length, crown height, phosphorus, CAI diameter, Chl-b, total chlorophyll, Chl-a, RWC and Potassium. CAI diameter showed strongest positive relation with crown height followed by crown length, Chl-b, RWC, MSI, total chlorophyll, nitrogen, potassium, plant dry weight, phosphorus, Chl-a and plant fresh weight. Crown height showed strongest positive relation with crown length followed by RWC, Chl-b, plant dry weight, plant fresh weight, phosphorus, root length, MSI, total chlorophyll and Chl-a. Crown length showed strongest positive relation with plant dry weight followed by plant fresh weight, root length, Chl-b, total chlorophyll, RWC, MSI, Chl-a and phosphorus. Root length has strongest positive relation with plant fresh weight followed by plant dry weight, Chl-b, total chlorophyll and Chl-a. Plant fresh weight has strongest positive relation with by plant dry weight followed by Chl-b, total chlorophyll and Chl-a. Plant dry weight has strongest positive relation with Chl-b followed by total chlorophyll and Chl-a. Nitrogen has strongest positive relation with MSI followed by Chl-a, RWC, total chlorophyll and TSS. Phosphorus has strongest positive relation with potassium. Chl-a has strongest positive relation with total chlorophyll followed by MSI, Chl-b and RWC. Chl-b has strongest positive relation with total chlorophyll followed by MSI and RWC. Total chlorophyll strongest positive relation with MSI followed by RWC. RWC has strongest positive relation with MSI. Carotenoids do not show any significant correlation with any parameter.

Table 4.13: Variability estimates and genetic parameters in *Dalbergia sissoo*

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)	
			Genotypic (%)	Phenotypic (%)				
PH	2.57	2.38-2.83	13.96	16.06	15.84	0.1	5.24	
CD	32.49	24.82-38.35	15.48	21.67	50.98	7.4	22.76	
CH	0.92	0.85-0.99	10.02	14.63	17.00	0.1	5.12	
CL	1.65	1.53-1.84	7.23	16.97	15.22	0.1	5.32	
RL	69.55	61.75-93.40	13.95	19.75	49.84	14.1	20.28	
LN	Rainy	1.82	1.04-2.24	30.34	33.14	83.84	0.9	57.23
	Spring	2.34	2.04-2.68	10.22	19.29	28.08	0.3	11.16
LP	Rainy	0.18	0.11-0.24	11.50	16.20	40.27	0.1	0.09
	Spring	0.18	0.13-0.23	17.67	26.22	45.42	0.1	24.53
LK	Rainy	0.88	0.63-1.02	32.68	34.37	90.40	1.0	64.01
	Spring	0.92	0.61-0.31	7.62	11.60	43.11	0.2	10.30
PFW	10.40	8.35-15.85	22.88	28.14	66.07	4.0	38.30	
PDW	5.73	4.60-8.55	21.54	26.79	64.65	2.0	35.67	
CHL-a	Rainy	12.11	8.98-15.85	19.14	21.82	76.88	4.2	34.56

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)	
			Genotypic (%)	Phenotypic (%)				
	Spring	12.87	9.21-17.50	33.31	33.80	97.09	8.5	67.60
CHL-b	Rainy	2.81	2.30-3.78	22.30	28.63	60.65	1.0	35.77
	Spring	7.13	6.12-8.55	66.21	67.33	96.69	6.3	34.11
Total CHL	Rainy	14.92	11.28-19.63	19.79	21.88	81.77	6.1	36.86
	Spring	20.00	15.33-26.05	19.02	21.28	76.86	6.7	35.01
CRTD	Rainy	0.03	0.02-0.05	18.92	20.45	10.47	0.1	12.61
	Spring	0.05	0.04-0.06	31.78	35.76	19.83	0.1	14.61
RWC	Rainy	49.87	42.55-56.74	4.15	5.67	53.61	4.1	6.26
	Spring	70.69	62.26-75.43	7.75	8.08	91.95	10.4	15.31
MSI	Rainy	57.50	53.24-62.56	13.32	13.87	92.28	14.0	26.37
	Spring	74.89	67.58-81.34	14.31	15.74	82.74	14.2	26.82
TSS	Rainy	28.87	24.56-36.32	12.97	15.63	68.88	6.4	22.18
	Spring	30.31	25.67-37.12	12.71	15.54	66.91	6.5	21.42

Note: PH- Plant height; CD- Collar diameter; CAI- PH- Current annual increment of plant height; CAI-CD- Current annual increment collar diameter; CH- Crown height; CL- Crown length; RL- Root length; LN- Leaf nitrogen; LP- leaf phosphorus; LK- Leaf potassium; PFW- Plant fresh weight; PDW- plant dry weight; CHL-a - Chlorophyll-a; CHL-b - Chlorophyll-b; Total CHL- Total chlorophyll; CRTD – Carotenoids; RWC - Relative water content; MSI - Membrane stability index; TSS -Total soluble sugars.

Table 4.14: Correlation coefficients among growth, biomass, minerals and physiological traits in *Melia dubia*

	PH	CD	CAI-H	CAI-CD	CH	CL	RL	PFW	PDW	LN	LP	LK	Chl-a	Chl-b	CHL	Carot	RWC	MSI
CD	0.997**	1																
CAI-H	0.998**	0.997**	1															
CAI-CD	0.997**	0.999**	0.997**	1														
CH	0.999**	0.995**	0.998**	0.994**	1													
CL	0.998**	0.998**	0.998**	0.997**	0.995**	1												
RL	0.967**	0.980**	0.970**	0.983**	0.960**	0.973**	1											
PFW	0.859*	0.884**	0.867*	0.892**	0.851*	0.867*	0.942**	1										
PDW	0.826*	0.857*	0.833*	0.864*	0.812*	0.840*	0.927**	0.992**	1									
LN	0.909**	0.907**	0.914**	0.914**	0.917**	0.897**	0.903**	0.913**	0.856*	1								
LP	0.689 ^{NS}	0.697 ^{NS}	0.695 ^{NS}	0.707 ^{NS}	0.702 ^{NS}	0.670 ^{NS}	0.744 ^{NS}	0.693 ^{NS}	0.634 ^{NS}	0.743 ^{NS}	1							
LK	0.604 ^{NS}	0.630 ^{NS}	0.619 ^{NS}	0.645 ^{NS}	0.595 ^{NS}	0.614 ^{NS}	0.750 ^{NS}	0.891**	0.882**	0.775*	0.677 ^{NS}	1						
Chl-a	-0.082 ^{NS}	-0.083 ^{NS}	-0.066 ^{NS}	-0.063 ^{NS}	-0.086 ^{NS}	-0.077 ^{NS}	0.030 ^{NS}	0.271 ^{NS}	0.258 ^{NS}	0.241 ^{NS}	0.071 ^{NS}	0.614 ^{NS}	1					
Chl-b	-0.262 ^{NS}	-0.279 ^{NS}	-0.248 ^{NS}	-0.262 ^{NS}	-0.264 ^{NS}	-0.258 ^{NS}	-0.203 ^{NS}	0.017 ^{NS}	0.001 ^{NS}	0.044 ^{NS}	-0.183 ^{NS}	0.366 ^{NS}	0.948**	1				
CHL	-0.142 ^{NS}	-0.148 ^{NS}	-0.126 ^{NS}	-0.128 ^{NS}	-0.145 ^{NS}	-0.137 ^{NS}	-0.045 ^{NS}	0.191 ^{NS}	0.177 ^{NS}	0.180 ^{NS}	-0.011 ^{NS}	0.540 ^{NS}	0.995**	0.976**	1			
Carot	0.719 ^{NS}	0.709 ^{NS}	0.731 ^{NS}	0.712 ^{NS}	0.716 ^{NS}	0.720 ^{NS}	0.733 ^{NS}	0.671 ^{NS}	0.626 ^{NS}	0.707 ^{NS}	0.715 ^{NS}	0.679 ^{NS}	0.162 ^{NS}	0.035 ^{NS}	0.123 ^{NS}	1		
RWC	0.679 ^{NS}	0.677 ^{NS}	0.693 ^{NS}	0.690 ^{NS}	0.683 ^{NS}	0.673 ^{NS}	0.730 ^{NS}	0.837*	0.785*	0.888**	0.662 ^{NS}	0.909**	0.623 ^{NS}	0.449 ^{NS}	0.574 ^{NS}	0.747 ^{NS}	1	
MSI	0.925**	0.943**	0.930**	0.945**	0.922**	0.926**	0.967**	0.957**	0.933**	0.921**	0.774*	0.788*	0.050 ^{NS}	-0.18 ^{NS}	-0.02 ^{NS}	0.772*	0.776*	1
TSS	0.732 ^{NS}	0.723 ^{NS}	0.741 ^{NS}	0.729 ^{NS}	0.740 ^{NS}	0.720 ^{NS}	0.746 ^{NS}	0.652 ^{NS}	0.588 ^{NS}	0.734 ^{NS}	0.906**	0.650 ^{NS}	0.083 ^{NS}	-0.09 ^{NS}	0.026 ^{NS}	0.929**	0.709 ^{NS}	0.772*

Note: PH- Plant height; CD- Collar diameter; CAI-H- Current annual increment of height; CAI-CD- Current annual increment collar diameter; CH- Crown height; CL- Crown length; RL- Root length; LN- Leaf nitrogen; LP- leaf phosphorus; LK- Leaf potassium; PFW- Plant fresh weight; PDW- plant dry weight; Chl-a - Chlorophyll-a; Chl-b - Chlorophyll-b; CHL- Total chlorophyll; Carot- Carotenoids; RWC- Relative water content; MSI- Membrane stability index; TSS- Total soluble sugars.

Table 4.15: Correlation coefficients among growth, biomass, minerals and physiological traits in *Dalbergia sissoo*

	PH	CD	CAI-H	CAI-CD	CH	CL	RL	PFW	PDW	LN	LP	LK	Chl-a	Chl-b	CHL	Carot	RWC	MSI
CD	0.894**	1																
CAI-H	0.929**	0.714 ^{NS}	1															
CAI-CD	0.932**	0.986**	0.807*	1														
CH	0.987**	0.912**	0.890**	0.944**	1													
CL	0.997**	0.879**	0.938**	0.919**	0.973**	1												
RL	0.907**	0.690 ^{NS}	0.916**	0.741 ^{NS}	0.833*	0.933**	1											
PFW	0.916**	0.708 ^{NS}	0.918**	0.759*	0.845*	0.940**	0.998**	1										
PDW	0.932**	0.732 ^{NS}	0.920**	0.779*	0.869*	0.953**	0.996**	0.998**	1									
LN	0.684 ^{NS}	0.804*	0.551 ^{NS}	0.813*	0.743 ^{NS}	0.652 ^{NS}	0.432 ^{NS}	0.459 ^{NS}	0.496 ^{NS}	1								
LP	0.797*	0.700 ^{NS}	0.817*	0.779*	0.836*	0.773*	0.578 ^{NS}	0.583 ^{NS}	0.601 ^{NS}	0.543 ^{NS}	1							
LK	0.723 ^{NS}	0.729 ^{NS}	0.755*	0.801*	0.741 ^{NS}	0.709 ^{NS}	0.518 ^{NS}	0.526 ^{NS}	0.531 ^{NS}	0.512 ^{NS}	0.923**	1						
Chl-a	0.786*	0.726 ^{NS}	0.775*	0.778*	0.757*	0.792*	0.764*	0.786*	0.795*	0.815*	0.456 ^{NS}	0.459 ^{NS}	1					
Chl-b	0.910**	0.906**	0.805*	0.916**	0.874*	0.919**	0.866*	0.883**	0.893**	0.735 ^{NS}	0.544 ^{NS}	0.581 ^{NS}	0.897**	1				
CHL	0.826*	0.778*	0.795*	0.822*	0.795*	0.834*	0.799*	0.821*	0.830*	0.812*	0.483 ^{NS}	0.494 ^{NS}	0.995**	0.935**	1			
Carot	0.082 ^{NS}	0.079 ^{NS}	0.124 ^{NS}	0.098 ^{NS}	0.033 ^{NS}	0.103 ^{NS}	0.162 ^{NS}	0.184 ^{NS}	0.149 ^{NS}	-0.286 ^{NS}	0.082 ^{NS}	0.282 ^{NS}	-0.017 ^{NS}	0.156 ^{NS}	0.020 ^{NS}	1		
RWC	0.855*	0.848*	0.770*	0.890**	0.887**	0.833*	0.666 ^{NS}	0.701 ^{NS}	0.721 ^{NS}	0.814*	0.727 ^{NS}	0.702 ^{NS}	0.823*	0.840*	0.841*	0.234 ^{NS}	1	
MSI	0.810*	0.850*	0.666 ^{NS}	0.855*	0.830*	0.794*	0.664 ^{NS}	0.693 ^{NS}	0.721 ^{NS}	0.927**	0.490 ^{NS}	0.446 ^{NS}	0.921**	0.894**	0.932**	-0.106 ^{NS}	0.883**	1
TSS	0.281 ^{NS}	0.319 ^{NS}	0.204 ^{NS}	0.342 ^{NS}	0.385 ^{NS}	0.231 ^{NS}	0.030 ^{NS}	0.059 ^{NS}	0.103 ^{NS}	0.783*	0.291 ^{NS}	0.112 ^{NS}	0.506 ^{NS}	0.247 ^{NS}	0.459 ^{NS}	-0.521 ^{NS}	0.530 ^{NS}	0.643 ^{NS}

Note: PH- Plant height; CD- Collar diameter; CAI- H- Current annual increment of height; CAI-CD- Current annual increment collar diameter; CH- Crown height; CL- Crown length; RL- Root length; LN- Leaf nitrogen; LP- leaf phosphorus; LK- Leaf potassium; PFW- Plant fresh weight; PDW- plant dry weight; Chl-a - Chlorophyll-a; Chl-b - Chlorophyll-b; CHL- Total chlorophyll; Carot - Carotenoids; RWC - Relative water content; MSI - Membrane stability index; TSS -Total soluble sugars.

CHAPTER-V

SUMMARY

Trees are a critical part of life on our planet because of their several direct and indirect benefits to the humankind and animal world as well. They deliver wood for making houses, furniture, timber, agricultural gear, plywood, paper, veggies, fiber, fuel wood, and many others uses. Area under forest and tree cover is 5.93% of the total geographical area and is very less than the minimum area required for sustainable environment (NFP 1952). To increase area under trees, government has to take different initiative such as afforestation and reforestation programmes. The rate of survival of these newly recruited seedlings in these programmes depends upon proper cultural operations, pre and post planting management practices. Of these, water availability is major challenge to afforestation programs in many parts of the tropical and temperate regions in the world especially in the seedling stage while seedling requires frequent irrigation in the summer months. If water is scanty in that region then water-saving technologies like application of water absorbant polymers that enhance plant establishment and growth. It is an established fact that the response of these hydrogel against drought-sensitive and drought-tolerant crop are differing. Keeping in view, the present study had been planned to study the effect of hydrogel on the growth, biomass, mineral nutrition and followed by physiology of plants in short and long rotation tree species like *Melia dubia* and *Dalbergia sissoo* grown on sandy loam soil amended with water absorbent polymers. The present study was under taken in the department of Forestry & Natural resources at Punjab Agricultural University, Ludhiana during the year 2021-22.

The physicochemical characteristic of the study site are measured at the starting and end of the experimental trial. The treatments consist of 7 levels of the hydrogel using the concentration 0, 25, 30, 35, 40, 45, 50 g/plant. Hydrogel was applied in the powdered form before planting the seedlings in pits size having $50 \times 50 \times 50 \text{ cm}^3$ ($1,25000 \text{ cm}^3$) volume. The seedlings were transplanted in the field in the month of February using a completely randomized block design at a spacing of $2 \times 2 \text{ m}$ with 8 plants per treatment and four replications. Observation on growth characteristics like plant height, collar diameter, current annual increment for height and diameter, crown height and length root length, plant fresh and dry weight; elemental concentrations of N, P and K in leaves on seasonal basis; and physiological characteristics like chlorophyll-a, chlorophyll-b, total chlorophyll, total carotenoids, relative water content, membrane stability index and total soluble sugars in leaves on seasonal basis. The experimental data were analyzed using analysis of variance technique using SPSS software.

In first experiment i.e., Effects of water absorbing polymer hydrogel on growth of *Melia dubia* showed significant differences among the traits studied. Treatment T2 (30 gm/pit

concentration of hydrogel) was found best in *Melia dubia* plantation which significantly increased the plant height, collar diameter, crown height and length, root length, plant fresh and dry weight. Minimum values were observed in control (without hydrogel application) followed by 50 gm/pit hydrogel. Maximum sapling height, collar diameter, plant fresh weight, plant dry weight, root length, crown height, crown length attained in *Melia dubia* plants were 3.99 ± 0.23 m, 61.82 ± 4.32 mm, 31.25 ± 3.09 kg, 15.25 ± 1.93 kg, 142.00 ± 10.05 cm, 2.38 ± 0.13 m, 1.61 ± 0.10 m, respectively which were observed in treatment T2 (30 gm/pit hydrogel). The highest value of current annual increment was recorded in treatment T2 (30g m/pit) for both plant height and collar diameter.

The physiological parameters of *Melia dubia* showed significant results. However, no definite pattern was observed except for chlorophyll, TSS and MSI. Treatment T2 (30 gm/pit hydrogel concentration) was found best for the elemental concentrations in leaves of *Melia dubia*. The maximum amount of N, P and K observed in leaves $2.52\pm 0.01\%$, $0.20\pm 0.01\%$ and $1.81\pm 0.09\%$, respectively in rainy season and $2.28\pm 0.01\%$, $0.18\pm 0.00\%$ and $1.68\pm 0.15\%$, respectively in spring season. Chlorophyll content was increased with increase in amount of hydrogel so the maximum total chlorophyll content (12.65 ± 0.49 mg/g in rainy season and 20.50 ± 0.90 mg/g in spring season) was perceived in treatment T6 (50 gm/pit). The highest amount for carotenoids (0.08 ± 0.12 & 0.08 ± 0.02 & 0.08 ± 0.02 mg/100g) were recorded in treatment T6 (50gm/pit), T2 (30 gm/pit) and T1 (25 gm/pit), respectively in rainy season and 0.09 ± 0.02 mg/100 gm was recorded in T2 (30 gm/pit) and same value in T3 (35 gm/pit) during spring season. The maximum relative water content ($57.54\pm 2.78\%$) and ($75.16\pm 1.86\%$) and membrane stability index (MSI) ($74.62\pm 1.20\%$) and ($79.81\pm 0.69\%$) was recorded for treatment T2 (30 gm/pit) in rainy and spring season, respectively. The maximum total soluble sugars (24.15 ± 1.01 mg/g) and (23.35 ± 1.00 mg/g) were recorded for treatment T1 (25 gm/pit) in rainy and spring season, respectively. Minimum values for all physiological parameters were recorded in plants grown under control except TSS in which the minimum values were observed in treatment T6 (50 gm/pit).

In second experiment i.e., “Effects of water absorbing polymer hydrogel on growth of *Dalbergia sissoo*” showed significant differences among the studied traits. The maximum value for the sapling height, collar diameter, plant fresh weight, plant dry weight, root length, crown height, crown length were 2.83 ± 0.28 m, 38.35 ± 4.13 mm, 15.85 ± 1.59 kg, 8.55 ± 0.78 kg, 93.40 ± 9.41 cm, 0.99 ± 0.09 m and 1.84 ± 0.19 m respectively were observed in treatment T3 (35 gm/pit). Minimum values for all above parameters were observed in control treatment.

The physiological parameters of *Dalbergia sissoo* did not show any definite pattern for most of the traits studied. The maximum nitrogen percentage ($2.24\pm 0.08\%$) was recorded for treatment T4 (40 gm/pit) and highest value of phosphorus ($0.24\pm 0.02\%$) and potassium ($1.02\pm 0.12\%$) were observed in treatment T3 (35 gm/pit) during rainy season and in the spring

season highest value of nitrogen (2.68 ± 0.09 %) is found in treatment T4 (35 gm/pit) and maximum phosphorus (0.23 ± 0.03 %) and potassium (1.31 ± 0.07 %) values were recorded in treatment T2 (30 gm/pit). The maximum total chlorophyll content for rainy season (19.63 ± 1.90 mg/g) and spring season (26.05 ± 0.75 mg/g) was observed in treatment T2 (30 gm/pit) and T3 (35 gm/pit), respectively. The maximum carotenoid content (0.05 ± 0.01 mg/100g) was recorded for treatment T3 (35gm/pit) and T4 (40 gm/pit) during rainy season and in spring season highest carotenoid content (0.06 ± 0.02 mg/100 gm) is observed in treatment T6 (50 gm/pit). In rainy season the highest relative water content (56.74 ± 0.61 %) was recorded for treatment T4 (40 gm/pit) and treatment T3 (35 gm/pit) shown the maximum value (75.43 ± 1.35 %) in spring season. The value of membrane stability index (MSI) is observed in treatment T3 (35 gm/pit) is (62.56 ± 1.64 %) which is highest during rainy season and in spring season uppermost value was (81.34 ± 2.27 %) observed in treatment T4 (40 gm/pit). The maximum total soluble sugars (36.32 ± 0.88 mg/g) and (37.12 ± 1.33 mg/g) were observed for treatment T1 (25gm/pit) in rainy and spring season respectively. Minimum values for all physiological parameters were observed in control except TSS in which the lowest values were recorded in treatment T5 (45 gm/pit).

The very high heritability was recorded in root length, plant fresh and dry weight, leaf N, P, chlorophyll-a, chlorophyll-b, total chlorophyll, total carotenoids, RWC, MSI and TSS in *Melia dubia* plants, while, plant fresh and dry weight, leaf N and K for spring season, chlorophyll-a, chlorophyll-b, total chlorophyll, MSI, TSS and RWC (spring season) in *Dalbergia sissoo*. Very high heritability coupled with high genetic advance as per cent of mean was observed for root length (75.02% with 41.60%) in *Melia dubia*, whereas, for MSI (14.2% with 82.74%) in *Dalbergia sissoo*. A significant positive correlation among the growth, biomass, elemental concentrations in leand and physiological paratmeters of *Melia dubia* and *Dalbergia sissoo* were observed but only few physiological parameters showed significant positive relationship. Chl-a, Chl-b and total chlorophyll has non-significant negative relation with most of the growth and biomass parameters and few physiological parameters. Plant height and collar diameter showed strongest positive relation with majority of growth, biomass and leaf elemental concentrations, beside, MSI showed highly significant positive correlation with all growth, biomass, leaf elements, carotenoids and RWC.

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