“Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya”

Thesis
By

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I.D. No. - 17368

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CERTIFICATE - I

This is to certify that the thesis entitled **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"** submitted in partial fulfilment of the requirements for the degree of **Master of Science in Forestry** with major in **Silviculture** of the College of Post-Graduate Studies, V. C. S. G. Uttarakhand University of Horticulture and Forestry, Bharsar, is a record of ***bonafide*** research carried out by Ms. **Pooja Uniyal, Id No. UUHF/17368** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

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This is to certify that the thesis titled, **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya, India"** submitted by **Ms. Pooja Uniyal, I.D. No. UUHF/17368** to VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India in partial fulfilment of the requirements for the degree of Master of Science **Forestry** in the discipline of **Silviculture** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner on **06th September, 2021 (02.00 PM).**

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ABSTRACT

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Thesis title - "Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"

The present investigation was conducted during July to December 2019 in the nursery block of College of Forestry, Ranichauri. *Celtis australis* is an important agroforestry tree species of Garhwal Himalaya and its plants are generally containerized grown which results in higher cost of transportation in the hills for carrying out plantation activities. Transportation of seedlings without containers might help in reduction of transportation cost therefore, the present investigation has been taken up to study the effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings. The experiment consists of three root pruning lengths i.e. 0 (control), 6 and 12 cm root pruning from collar region and four nitrogen doses i.e. 0, 50, 100 and 150 Kg/ha to study the growth performance, physiological characteristics and nutritional content and uptake of the seedlings. Root pruning and nitrogen application significantly increased morphological, physiological and nutritional parameters. The light pruned (12 cm) seedling showed better performance as compared to severely pruned (6 cm) seedlings. Application of nitrogen up to 100kg/ha increased morphological, physiological and nutritional parameters of *C. australis* seedlings. Root pruning at 12 cm coupled with nitrogen application at the rate of 100kg/ha showed a significant increase in survival percent, collar diameter, number of leaves, white root regeneration, biomass (fresh and dry weight basis), chlorophyll and NPK content and their uptake in seedlings. Hence root pruning at 12 cm from the collar region with 100kg N/ha application may be suitable for better establishment of *Celtis australis* seedlings in this region.

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वन उत्पाद एवं उपयोगिता)

विषयः "रूट प्रूनिंग तथा नाइट्रोजन उपयोग का गढ़वाल हिमालय में खड़ीक (सेल्टिस ऑस्ट्रेलिस) के पौध प्रदर्शन पर प्रभाव"।

खड़ीक में रूट प्रूनिंग तथा नाइट्रोजन उपयोग के प्रभाव का अध्ययन वानिकी महाविद्यालय रानीचौरी, टिहरी गढवाल (उत्तराखंड) के नर्सरी ब्लॉक में जुलाई से दिसम्बर 2019 में किया गया। खड़ीक के पौधों को आमतौर पर पॉलीथीन की थैलियों में उगाया जाता है जिसके परिणामस्वरूप पहाड़ी क्षेत्रों में वृक्षारोपण गतिविधियों के लिए अधिक खर्च वहन करना पडता है। पॉलीथीन के बिना पौधों की रोपाई में लागत को कम करने में मदद मिल सकती है इसलिए वर्तमान जॉच में सेल्टिस ऑस्ट्रलिस पौधों में वृद्धि के प्रदर्शन और उनकी स्थापना पर रूट प्रूनिंग और नाइट्रोजन उपयोग के प्रभाव का अध्ययन किया गया जिसमें कॉलर क्षेत्र से रूट प्रूनिंग की तीन लंबाई (0से0मी0, 06से0मी0 तथा 12 से0मी0) एवं चार नाइट्रोजन अनुप्रयोग (0कि0ग्रा0, 50कि0ग्रा0/हे0 100कि0ग्रा0/हे0 तथा 150 कि0ग्रा0/हे0) के साथ निर्धारित किये गये। लगाए गए पादपों का अध्ययन उनके वृद्धि प्रदर्शन, फिजियोलाजी और न्यूट्रिन्ट संबधी स्थिति के लिए किया गया। रूट प्रूनिंग और नाइट्रोजन उपयोग ने अकारिकी, फिजियोलाजी और न्यूट्रिन्ट संबधी स्थिति में महत्वपूर्ण परिणाम दिखाया। हालॉकि 12सेमी0 रूट प्रूनिंग पादपों ने 6सेमी0 रूट प्रूनिंग हुऐ पादपों की तुलना में बेहतर प्रदर्शन दिखाया। नाइट्रोजन उपयोग से खड़ीक के लगाए गए पादपों में मॉरफोलोजी, फिजियोलाजी और न्यूट्रिन्ट संबधी मापदंडो में वृद्धि पायी गयी। 12से0मी0 रूट प्रूनिंग तथा 100कि0ग्रा0/हे0 के संयोजन से उत्तरजीविता, कॉलर विकास, पत्तियों की संख्या, सफेद जड़ पुनर्जनन, जैवभार (ताजा व शुष्क वजन पर आधारित), क्लोरोफिल और एन0 पी0 के0 में वृद्धि पाई गई। अतः इस क्षेत्र में सेल्टिस ऑस्ट्रेलिस पादपों के बेहतर प्रदर्शन और पौध रोपण क्षेत्र में पौधों को पहुँचाने की लागत को कम करने के लिए पौधशाला में पौधों को 12से0मी0 रूट प्रूनिंग के साथ 100कि0ग्रा0 नाइट्रोजन/हे0 का इस्तेमाल किया जा सकता है।

अमोल वसिष्ठ
(सलाहकार)

पूजा उनियाल
पूजा उनियाल
(लेखिका)

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CHAPTER 1 INTRODUCTION

The Himalayas is the youngest and tallest mountain ranges of the world, distributed in northern part of India. It covers 18% of the geographical region of the India. The Himalaya is not only important for ecosystem services, climate variation and rich variety of flora & fauna but also provides resources for human life and supply sufficient amount of water to the large part of India and is also rich in cultural diversity of people and tribal communities (Singh *et al.,* 2006).

Uttarakhand is a North Indian state, having a geographical area of 53,483 km^2 which is 1.63% of the total geographical region of the India (ISFR, 2019). It has a rich floristic diversity comprising 7,869 floral species (SFRI, 2005). In Uttarakhand, the Garhwal Himalaya region is mostly covered with wild edible fruits, medicinal plants and other plant species, which are utilized by the villagers in the forms of medicine, fuel, food, fodder, agricultural implements and timber (Gaur, 1999 and Saklani, 2011). The hilly areas of Uttarakhand are dominated by several traditional and modern agroforestry systems and each agroforestry systems have potential to store abundant amount of carbon and also provide fuel, fruits, fodder, fibres and organic fertilizers (Bijalwan *et al.,* 2016). The existence of forest trees species without agroforestry system is very strain in hilly region, because the trees not only supplement the fuel, fodder, fibre, fruits, timber etc., but also reduce the soil erosion and land sliding in fields. Where trees under agroforestry systems improves the quality of soil through nitrogen fixation, add organic matter through litter fall etc., and also helps in controlling water logging, checks acidification and decreases the pressure on natural forests for fodder and fuel, and also increases the local diversity (Makundi and Sathaye, 2004).

Celtis australis is an important agroforestry tree species of Garhwal Himalayas and it's generally grown in conventional agroforestry systems for main

purpose of fodder (Gaur, 1999). It is a true multipurpose tree species which was initially placed into the family of *Ulmaceae* but was later reclassified into the family of *Cannabaceae* (Systma *et al.*, 2002). It is a native tree species of the Western Himalaya (Singh *et al*., 2006). *Celtis australis* is grown for the purpose of fodder, fuel, timber and other uses in or on all sides of agricultural field and plays a very important role in socioeconomic structure in hilly areas because it is highly palatable, nutritious and tannin-free green fodder for cattle and particularly during the period of scarcity of green fodder (Yadav and Bisht, 2013). The branches and leaves of C*eltis australis* can be harvested year to year during the scarcity of other fodder and foliage (Singh *et al.*, 2006). In case of North West Himalaya, *Celtis australis* is usually grown under traditional agroforestry system for fodder production and it's a usually associated with *Ficus spp*, *Quercus spp*, *Bauhinia spp* and *Grewia optiva* (Gaur, 1999). It can be grown in any type of good soil, well-drained loamy soil (Chittendon, 1956) and sandy soil and on dry gravels also. It carries the deep spreading roots and also has a fibrous root system (Chiej, 1984) and roots are found very drought resistance once established (Komarov, 1968).

Celtis australis has been found favourable for the coppice farming in the formation of vigour plantation (Bisht, 2003). It also provides narrow products of forage, fuel wood and ecological infrastructure for sustained yield. The wood of *Celtis australis* is stiff, with grey coloured hardwood and yellow sapwood and is suitable for carving, making musical instruments, sports equipments and paddles, etc and the flowers are small, hermaphroditic or polygamous, apetalous, with 4 to 5 stamens, appearing on young shoots. The fruit is round up to 1cm wide, with a sugary and eatble cover (Jovanovic, 1971: Brus, 2005).

Roots are one of the most important plant organs which are commonly found under the soil with the positive gravitropism growth direction to provide a

water or nutrient sources to the whole plant system. The roots are more often in yellow or white colour and compared to the above ground plant parts such as stems or leaves which get more attention, where roots get less attention because their existence is underground or below soil. Roots play an important role in supporting the plant for better growth or for long time survival of plants, providing support to stems and shoots above the ground and also supporting nutrients and water absorption under the ground and serving as nutrient storage in some species (Tjitrosoepomo, 2009).

A good and well established portion of plant root system with respect to its shoot system is more important and can be attained by the root pruning techniques. Root pruning is a technique to regenerate and nurture tree size including canopies and roots for attaining to maximum production (Widodo, 1995; Marini, 2014). Root Pruning of plants is actually an old practice and technique which is mostly practiced to arboriculture, including landscape and forest tree nurseries (Gilman, 1992).

Root pruning is one of the most familiar and important practice of removing the small portion of roots from the plants root system (Gazal *et al*., 2004). Root pruning reduce root circling and increases the growth of secondary root branching and encourage root renewal after implanting (Arnold and Struve, 1993; Arduini *et al*., 1994; Crawford, 1997). Root pruning contributes towards improving tree root and shoot performance and physiological responses (Geisler and Ferree, 1984) which helps in to stimulate the new roots which is necessary to carry on growth. Root pruning also reduces the oldest growth balance of trees and change their hormone levels and nutrient distribution and also assimilation abilities. Root pruning is also recommended for easier planting (Dierauf and Garner, 1978).

The important aim of the root pruning practice is to manage the competition of trees and crops for resources and also reduce the reproductive growth of trees below high solidity planting structure (Khan *et al*., 1998). A fully established or structured root system with many fine roots, and most important character of high grade seedlings (Aldhus, 1994; Asin *et al*., 2007). In the hills, transportation of root pruned seedlings in comparison to transportation of containerised grown seedlings from nursery to plantation sites reduce transportation costs and better establishment.

Plants need nutrients to grow and fertilizers are a good source of nutrients. Nitrogen is the most important nutrient element which is essential for the endurance of all livelihood (Rosolem, 2017; Vitousek, 1982). Nitrogen is an essential and important element which is required for plant growth and their development. Generally fertilizers are used to maintain and influence the nutritional circumstances of different cropping structure. Once nitrogen fertilizers are applied to cropping systems, the fertilizers are directly absorbed by plants root system (Liu *et al*., 2014).

Split doses of nitrogen fertilizer is used at distinct growth periods of crop to increase its productivity (Zenawi and Mizan, 2019). Fertilization increases leaf nutrient, dry matter, fruit yield and chlorophyll content (Raese *et al*., 2007). Fertilization can also improve leaf surface area and thus increases the process of photosynthesis in plants (Yang and Luo, 1991). Excess use of nitrogen fertilizer enhances and promotes the vegetative growth of plants (Sun and Bian, 2011). Since the previous 50 years, the yield and productivity of different crops increased globally due to the high use of nitrogen along with good management practices (Smil, 2001).

Therefore, keeping in view the above points into consideration, the present topic entitled “Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya” has been taken for study with the following objectives:

1. To study the effect of root pruning on the survival and establishment of *Celtis australis* seedlings.
2. To study the effect of nitrogen application on the survival and establishment of *Celtis australis* seedlings.

CHAPTER 2 REVIEW OF LITERATURE

In this chapter, a brief review of literature pertaining to the present investigation entitled **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"** has been cited. The available literatures relevant to this topic have been discussed under proper heads and subheads:

- **Effect of root pruning on plant growth**

Sutton (1967) observed the height increments of *Picea glauca* and *Picea abies* after root pruning were significantly inferior in the second year than in the first year. Whereas the percentage increases in total root lengths (of all roots 1cm or more then 1cm long) in root pruned trees which were twice those of control trees and recommended the root pruning at 5-10cm depth for *Picea glauca* and *Picea abies.*

Dykstra (1974) stated that undercutting depth may affect root-regeneration of lodgepole pine (*Pinus contorta*) seedlings. The results revealed that the better growth in length and dry weight of the roots were found where the seedling was undercut at 3 inches depth in *Pinus contorta* var. Latifolia.

Sterling and Lane (1975) observed the growth and establishment of root and shoot pruned yellow poplar seedlings on two sites. In yellow poplar seedlings, the roots were pruned at 20cm and shoots were pruned at 10cm, which significantly increased the growth of plant throughout the growing season and had a greater height than other treatments.

Geisler and Ferree (1984) conducted an experiment to evaluate the effect of root pruning on net photosynthesis, waters relation and development of young golden delicious apple tree. The result revealed that the root pruning was effective in increasing production, reducing shoot growth and persistently decreasing root density in the soil.

Singh *et al*. (1984) studied the effect of root clipping on the growth of transplanted spruce seedlings and found that the root pruning at 7.5-10 cm increased the plant height and gives the best growth in terms of plant height, dry weight, root collar diameter and root length in *Picea smithiana.*

Wang (1984) conducted an experiment on effects of turning up seedbed soil on growth of young seedlings of *Dalbergia obtusifolia.* He reported that the main root cut at 5cm below ground level and the stem cut at 5cm above ground level gives maximum lateral root development and seedling growth in *Dalbergia obtusifolia.*

Gilman (1992) studied the influence of root cutting prior to transplanting on development of southern magnolia in the landscape.The difference was not found in post-transplanting growth among root pruned treatments because trees grew slightly faster as comparison of unpruned trees after one year of transplanting, where in second and third year the growth rates were equal for both unpruned andpruned trees after transplanting.

Walkenhorst (1993) conducted an experiment on planting techniques and root development. In which oak and beech seedlings were root pruned at a depth of 14-15cm and 18-20cm at the end of their 1st and 2nd growing season respectively and he found a good success after outplanting and also an increment in shoot:root ratio of 2:1 to 3:1.

Korwar and Radder (1994) observed the effect of root pruning and cutting interim of *Leucaena* hedgerows on the performance of alley cropped with rabi sorghum. They observed that the height of sorghum plant was significantly increased by the root pruning and further revealed that the root pruning considerably reduced the competition between crop and hedgerows.

Kerketta *et al.* (2017) observed the impact of root cutting on root morphology and stem of poplar (*Populus deltoides*) clones, and revealed that

the root pruned at 20cm length gave lowest result whereas, the root pruned at 5 cm length showed best result for development of *Populus deltoids* clones. Through the root pruning treatments, the survival percentage, leaf area, sprout length, root diameter, collar diameter, number of lateral roots and root length were remarkablyaffected and no-significance distinction of poplar clones were noticed on sprout length, root length, no. of lateral roots and on survival percent.

Gao *et al.* (2018) studied the impact of root cutting radius and time on yield of tuberous roots and resources allocation in a crop of *Helianthus tuberosus L.* The results revealed that the root, tuber, stem biomass were improved whereas tuber biomass was increased by 23.48% to 50.32% and the root cutting radius at 4/5R improved the largest tuber biomass at (T_2) 65 days seedling stage, root-shootproportion at (T_5) 115 days seedling stage and stem-leaf ratios at (T_3) 80 days seedling stage which were found below the different root pruning treatments and higher than control treatment.

Bose *et al*. (2019) conducted an experiment to study the effect of root pruning on shoot growth and flowering of mango cv. alphonso grown under ultra high density planting system. Two different groups of trees were root pruned *viz*., one during June and another during October at three different intensities *viz*., 30 cm, 45 cm, and 60 cm from the trunk in circular fashion to a depth of 60 cm. The result revealed that panicle emergence was advanced by ten days; also 50% of flowering was attained much earlier in root pruned trees when compared to the unpruned trees.

- **Effect of fertilizer on plant growth**

Pires and Silva (1964) applied fertilizer for *Eucalyptus salinga* seedlings and found that the doses of 0.0572g nitrogen and 0.0574g P_2O_5 per seedlings gives a significant response.

The forest department of Himachal Pradesh (1975) conducted the

study in which nitrogenous and phosphorous fertilizers were applied on shisham and khair seedlings to improve the growth. The four months old seedlings of *Dalbergia sissoo* and *Acacia catechu* increased the growth by applying the fertilizer dose of 0.6gm of calcium ammonium nitrate in polybag.

Narwal *et al*. (1977) studied the effect of nitrogen and phosphorus levels with varying seed rates and fodder yield and quality of dinanath grass and found that the dry fodder yield of dinanath grass significantly increased with the use of nitrogen and phosphorous fertilizer.

Chauhan and Khosla (1978) studied effect of application of fertilizers on growth of *Pinus roxburghii* sargent seedlings. They applied a Calcium Amonium Nitrate (CAN) fertilizer to container grown seedling of *Pinus roxburghii* at the rate of 0.5-0.2gm/plant as single dose and split dose. They found that the single dose only increased shoot length and collar diameter but had a little effect on the roots whereas the split dose showed and proved significantly better than single does and also increased root length and diameter.

Dwivedi *et al*. (1980) studied the effect of nitrogen and phosphorous on quantity and quality of herbage of *Chrysopogon fulvus* at Jhansi. The result revealed that doses of nitrogen and phosphorous fertilizer significantly increased the forage yield of *Chrysopagon fulvus*. The highest dry matter production was obtained with application of 90 kg N/ha and 40kg P_2O_5/ha and gives maximum crude protein (5.74%), Ca (0.59%) and P (0.113%) contents.

Pareek *et al*. (1983) observed nutrient uptake and dry matter production of palmarosa oil grasss under different levels of N, P and K fertilizers and found thatthe nutrient uptake significantly increased by the use of nitrogen fertilizer in palmarosa whereas due to the fertilization of nitrogen, the nutrient uptake of phosphorous was not affected.

Maheshwari *et al*. (1984) studied fertilizer needs of palmarosa oil grass (*Cymbopogon martini* stapf. Var. motia) under rainfed condition and reported

that application of 30% and 60% kg Nha^{-1} significantly increased the palmarosa herbage yield with 18.5% and 29% respectively compared with control.

Rao (1985) reported the impact of different extent of phosphorous and nitrogen on development and chemical constitution of *Celtis australis* Linn. and *Acacia mollissima* willd. The doses of nitrogen at the rate of 80kgN/ha significantly increased the fresh weight and dry weight of root and shoot and also improved the root length and plant height in *Celtis australis* and *Acacia mollissima.* Due to the nitrogen fertilization, the nutrient uptake of nitrogen was increased whereas nutrient uptake of phosphorous and potassium were depressed.

Bhardwaj *et al*. (1986) studied the effect of seed weight and nitrogen levels on growth and development of *Bahuinia variegata*. The doses of nitrogen at the rate of 75kg/ha increased the maximum height of plant at 35.10cm and collar diameter at 2.62nm in *Bahuinia variegata.*

Rao and Rao (1986) studied biomass accumulation and nutrient uptake in java citronella (*Cymbopogon winterianus jowitt*). They observed that the increased amount of nitrogen and phosphorous increased the nutrient uptake in *Cymbopogon*.

Chinnamna *et al*. (1988) reported the effect of fertilizers and harvest intervals on yield, nutrient composition and nutrient uptake of palmarosa. They stated that higher amount of nutrients was observed by the application of nitrogen and phosphorous fertilizer in palmarosa grass.

Sanginga (1988) studied the nodulation and development of few nitrogen fixing trees in correlation to nutrient volumes and rhizobium in Nigeria, Zaire and Zimbabwe and observed that the shoot weight significantly increased by 2-3 times with the application of Phosphorous at the rate of 250mg/5kg of soil as against of non-fertilized seedling in *Leucaena leucocephala*.

Arnold and Struve, (1993) studied the root diffusion and nutrient

uptake of coarse-rooted trees grown in Cupric Hydroxide treated containers. The result revealed that the seedling grown in $Cu(OH)_2$ treated containers, had more Cu than non-treated seedlings and also had a higher total Ca and Mg concentration at transplanting in the most plant tissue and higher total Zn and nitrogen attentiveness at the end of the growing season than non-treated seedlings.

Lal (1993) studied the effect of nitrogen level, time of application and spacing on growth of seedling of *Ulmus laevigata* royle. The result said that the biomass, seedling height increased with the application of Nitrogen fertilizer at the rate of 80kg/ha^{-1} and collar diameter increased over other Nitrogen levels in *Ulmus laevigata.*

Raese *et al*. (2007) studied the nitrogen dressing effects on fruit quality, cover crop and soil nutrients, leaf color and nitrogen content, biennnial posture and cold toughness of 'Golden Delicious'. The result revealed that nitrogen concentration of *Dactylis glomerata* (orchardgrass) blades was increased at the high rate of nitrogen doses which also increased cover-grass growth. Fruit had lower firmness and greener peel, titratable acidity and soluble solids content by the higher rate of nitrogen doses.

Liu *et al*. (2014) conducted studies on the impact of nitrogen fertilizers on the nitrate content and growth of lettuce (*Lactuca sativa* L.). They found that the total concentration of nitrate in lettuce and nitrogen concentration in soil increased as the quantity of nitrogen fertilizer increased. Where they recommended the amount of inorganic fertilizer as 200 kg N ha^{-1} is used as standard of comparision and 200kg N ha^{-1} as organic fertilizers which have significantly wider and longer leaves, higher shoot and less concentration of nitrate.

Khursheed and Mahammad, (2015) reported the impact of contrasting nitrogen fertilizers on yield and growth of wheat. They found that the fertilizer of nitrogen significantly increased and improved plant height, flag leaf area, shoot dry weight, number of tillers, leaf chlorophyll content, number of spikes

plant -1, grain yield, nitrogen and grain protein content and thousand seed weight tested parameters of growth by using Ammonium sulfate, Diammonium phosphate and Urea fertilizer.

Razaq *et al*. (2017) conducted studies on the effects of phosphorous and nitrogen on the development and root structure of *Acer mono*. The results revealed that application of both 10gm nitrogen and 8gm phosphorous significantly increased the plant height, chlorophyll content, root collar diameter and root morphology and the highest nitrogen and phosphorous level showed that they can be used to improve the seedling growth and health during the nursery period.

Zenawi and Mizan, (2019) reported the impact of nitrogen fertilization on the development and seed yield of sesame (*Sesamum indicum* L.) and the result indicate that the yield and growth of sesame are highly influenced and developed by the application of nitrogen fertilizer. Nitrogen fertilization also increases uptakes of other nutrients, such as P and K and some micronutrients. In the potential areas, the doses of Nitrogen fertilizer to 46–100 Kg N/ha gives higher yield & lowering the doses of nitrogen to less than 46 kg N/ha in marginal areas is economical.

- **Effect of root pruning and nitrogen application on plant growth**

Narsaiah (1990) conducted two separated field experiments and revealed that the growth and nutrient uptake by Vetiver was more with 10cm root pruning either alone and in combination with fertilizers (with and without Nitrogen as well as P_2O_5 each @40Kg ha) and gives better establishment at earlier then the 5cm pruning and number pruning.

Warren (1993) studied establishment and nutrient attentiveness in flowering dogwood after fertilization of nitrogen and dormant root pruning. He found the dry weight and leaf area of *Cornus florida* seedlings increased with the increasing amount of nitrogen where it is decreased with increasing root pruning and after 45 and 90 days the relative growth rate and root dry weight increased with increasing root pruning and it is decreased with

increasing amount of nitrogen. The nitrogen content highly found in all plant parts due to the increasing amount of nitrogen fertilization and root pruning helped in increasing the percentages of P% in new stem and root, K% in root and Mg% in new stems.

Bar-Tal *et al*. (1994) studied impact of root pruning and N-NO3 solution concentration on nutrient uptake and transpiration of tomato plants. They found the root weight uptake was higher in root pruned plants where N content in per plant decreased by the root pruning and did not affect the per unit dry matter. The nutrient uptake of plants with intact and pruned roots increased with the increasing the solution of nitrate concentration from 1.5 to 9.0mm.

Munyanziza and Oldeman (1995) conducted field endurance strategies, root pruning, growth and fertilization in the nursery of *Pterocarpus angolensis* D.C. and found the seedling growth of *Pterocarpus angolensis* was sharply depressed by the root pruning. In favor of shoots, the ratio between root and shoot disturbed by the nitrogen and phosphorus fertilization and inhibited nodulation.

Vasishth *et al*. (2007) studied the effect of root pruning and nitrogen application on post planting survival, growth and establishment of *Acacia catechu* willd. seedlings. They observed that the 10 cm pruned seedling showed higher growth and biomass production in both winter and monsoon planting seasons. The application of fertilizer up to 80kgN/ha increased plant growth, biomass and also increased the NPK content and their uptake in the seedlings.

Balliu *et al*. (2012) studied the effects of root pruning on seedling's growth and stand development rate of watermelon grafted seedlings. They found that the root pruned splice grafted seedlings (RPSG) gives significantly higher relative growth rate due to higher net assimilation rate than the splice grafted seedlings. In case of transplanted seedlings, the stand establishment rate was significantly reduced due to the increase of nutrient solution salinity,

but again the significantly higher values were recorded for root pruned splice grafted seedlings.

Kasprzyk and Jastrzębowski (2016) studied impacts of root triming and fertilization on biometric traits of two-year-old seedlings of *Fagus sylvatica L* and they found that the root pruned seedlings should be fertilized using the suggested amount of nitrogen fertilization (25Kg/ha) and had a significant difference between both pruning treatments (control and 12cm pruning) ($p=0.00$) and also for the interaction of both treatments ($p=0.019$). No significant effect on seedling height could be observed by the doses of nitrogen fertilization. If the root is not pruned during the second growth year so it is sensible to decrease the amount of nitrogen fertilization as half the suggested amount, $25Kg/ha^{-1}$.

Fang *et al.* (2017) studied the effect of root pruning and nitrogen fertilization on growth of young 'fuji' apple (*Malus domestica* borkh.) trees. The result revealed that root pruning with nitrogen fertilization increased fine root length ($\leq$1.0 mm diameter) and decreased coarse root length, where root pruning without nitrogen fertilization decreased coarse root length (2.0-4.0 and >4.0 mm diameter) and water use efficiency and net photosynthetic rate increased with the combination of root pruning and nitrogen fertilization while root pruning without fertilization increased transpiration rate and leaf chlorophyll content in young 'fuji' apple.

CHAPTER 3 MATERIALS AND METHODS

The present investigation entitled "**Effect of root pruning and nitrogen application on post planting survival, growth and establishment of *Celtis australis* seedlings in Garhwal Himalaya, India**" was carried out during July to December 2019 in experiment fields of forest nursery block of College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand. The details of the site characteristics, material used and experimental methodology followed during the course of investigation are described in this chapter under the following heads:

3.1 Experimental site-

The field experiment was conducted during July to December 2019 in the experiment fields of College of Forestry, Ranichauri situated at an altitude of approximately 1850 m asl between 30˚15˚N latitude and 78˚ 30˚ E longitudes in the mild hills of Uttarakhand in Tehri Garhwal (Fig. 3.1).

3.2 Climate and weather-

The average monthly minimum temperature ranged from 0.6˚C to 15.4˚C while, average maximum temperature varies was from 12.8˚C to 23.4˚C during the period of investigation from July to December months. A total 427.8 mm rainfall was received during the period of investigation which was 176.5mm in the month of july followed by 172.2 mm (August), 139.1 mm (September), 61.1 mm (October), 27.9 mm (November) and 27.5 mm (December) 2019 (Fig- 3.1).

3.3 Soil characteristics-

A composite soil sample was collected from the field at a depth of 0-15 cm and then dried, processed and used for chemical analysis. The details of initial physico-chemical properties of soil are presented in Table 3.1.

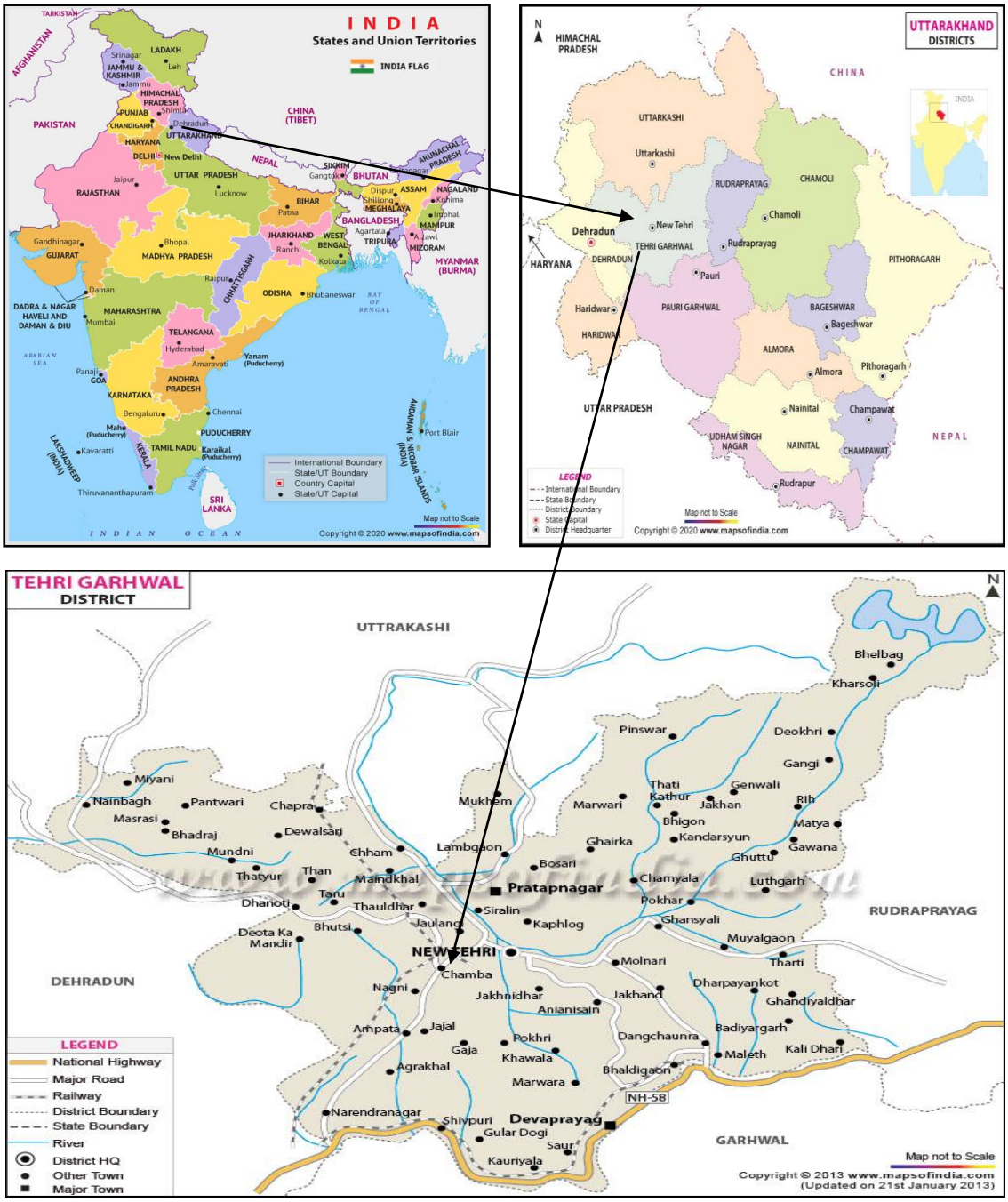

Fig. 3.1: Location of experimental site.

Source: https://www.mapsofindia.com/
https://www.mapsofindia.com/maps/uttarakhand/
https://www.mapsofindia.com/maps/uttarakhand/districts/tehrigarhwal.htm

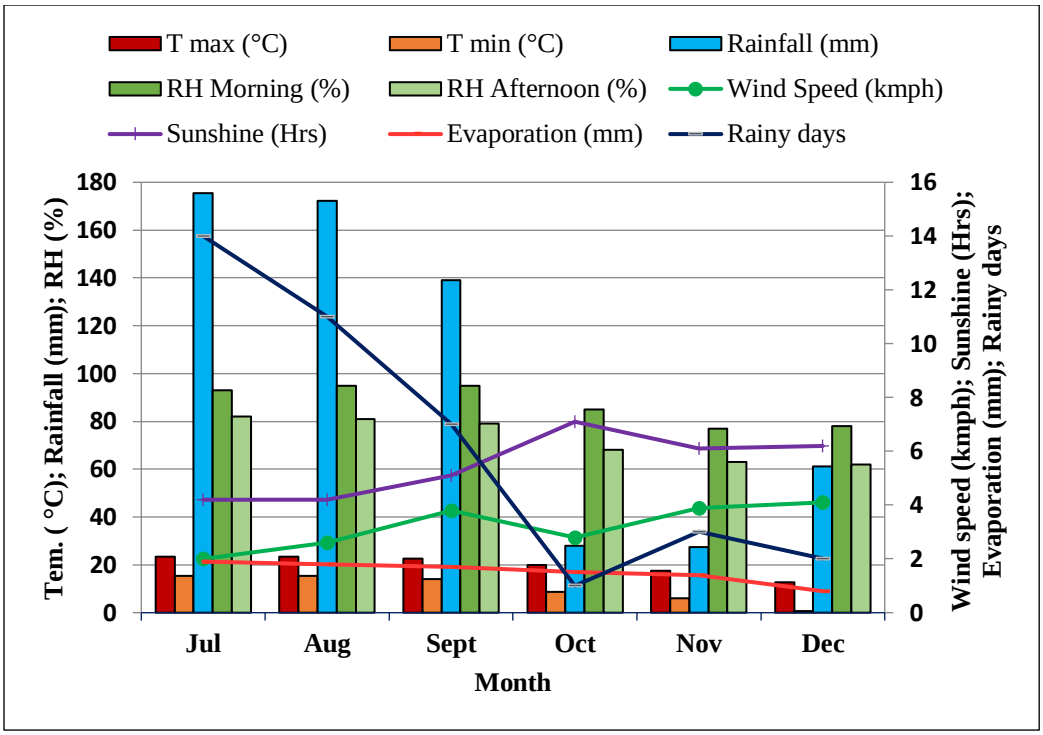

Figure 3.2: Metrological data observed during 2019 at Agromet Observatory, Ranichauri

Table 3.1: Physico chemical properties of experimental fieldtab

Soil properties	Value obtained	Method employed
pH	6.08	Blackman glass electrode pH meter (Jackson, 1967)
Available Nitrogen	141.12kg/ha	Alkaline $KMnO_4$ method (Subbianh and Asija, 1956)
Available Phosphorous	19.65kg/ha	Olsen's extraction method (Olsen *et al*, 1954)
Available Potassium	112kg/ha	Neutral normal NH_4OA_C Flame photometry method (Stanford and English,1949)
Organic carbon	1.55kg/ha	Walkely and black's method (1934)

3.4 Experimental details-

One year old seedlings were taken from the forest nursery, College of Forestry, Ranichauri. The experiment consists of two treatment root pruning and nitrogen applications. Three root pruning length (Control, 6cm and 12cm pruning from the collar region) and four fertilizer doses (0 Kg/ha, 50 Kg/ha, 100 Kg/ha and 150 Kg/ha) which was decided on the basis of physico-chemical properties of the soil. The field experiment was laid out in Randomized Block Design (RBD) with three replications. The details of experiments and treatments are given as below-

Table 3.2: Details of experiment-

S. No.	Particulars	Details
1.	Name of species	*Celtis australis* (Kharik)
2.	Age of species	1 year old
3.	Fertilizer used	CAN (Calcium ammonium nitrate) with 25% of available Nitrogen
4.	Field preparation	Using power tiller
5.	Planting time	Mid July (from 13-17July)
6.	Plot size	2×2.4m
7.	Pit size	10-15cm deep
8.	Plants per plot	20
9.	Spacing from plant × plant	50×50cm
10.	Spacing from row × row	48×48cm
11.	Total number of replications	3
12.	Total no. of treatment combinations	4×3
13.	Design	Factorial RBD (Randomized block design)

3.5 Details of treatments-

Table 3.3: Treatment details

Treatment	Treatment details
Root pruning	
(L_1)	Control (0cm)
(L_2)	6cm
(L_3)	12 cm
Nitrogen application	
(N_1)	Control
(N_2)	50 Kg/ha
(N_3)	100Kg/ha
(N_4)	150Kg/ha

3.5.1 Field preparation

The preparation of plot was done with the help of power tiller and was leveled with wooden plank.

3.5.2 Transplanting-

The one year old seedlings were root pruned from the collar region at given length of control (without pruning), 6cm and 12cm and then transplanted into the plots on13/July/2019.

3.5.3 Fertilizer application-

The doses of fertilizer were pre decided on the basis of soil analysis and was applied in two split doses, half doses at the time of planting and another half after fifteen days of planting.

3.5.4 Irrigation-

The manual irrigation was done as per the requirement**.**

3.5.5 Weeding-

Manual weeding was done after every 20 days.

3.5.6 Digging out-

Two plants of *Celtis australis* were dugout and uprooted from each plot at every month (from August to December) for taking the observations.

3.6 Observations recorded-

The observations on growth parameters and nutrient content were recorded at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150DAP (days after planting) from each plot. The chlorophyll content was recorded after 60 DAP and 120 DAP (days after the planting).

3.6.1 Plant growth parameters-

Growth of plants was recorded as follows:

3.6.1.1 Shoot height (cm)-

Shoot length of uprooted seedlings was measured from collar region to top of the shoot with the help of measuring tape.

3.6.1.2 Root length (cm)-

Root length of uprooted seedlings was measured from collar region to tip of the root with the help of measuring scale.

3.6.1.3 White root regeneration-

The number of new roots of uprooted seedlings was counted from the plants and the average values were calculated.

3.6.1.4 Collar diameter (cm)-

Collar diameter of uprooted seedlings was measured at the collar region of the stem of two randomly selected plants from each plot by using Vernier calliper and the average was recorded.

3.6.1.5 Number of leaves per plant-

Total numbers of leaves of uprooted seedlings were counted for two randomly selected plants from each plot and its mean values were calculated.

3.6.1.6 Fresh weight of root, shoot and leaves (g)-

Fresh weight of uprooted seedlings was recorded from two randomly selected plants from each plot. The fresh weight of root, shoots and leaves were individually recorded after harvesting and the averaged values were calculated and the fresh weight matter was expressed in g/plant.

3.6.1.7 Dry weight of root, shoot and leaves (g)-

Dry weight of uprooted seedlings was recorded from two randomly selected plants from each plot. The dry weight of root, shoot and leaves were individually recorded and dried in oven at 104℃ for 72 hours (till sample obtained constant weight) and the mean values were calculated and the dry matter weight was expressed in g/plant.

3.6.2 Chlorophyll content–

For determination of chlorophyll content, the 5g fresh leaf sample were taken and the leaves was chopped first and then grind with the help of mortar and pestle, where 10 ml of Acetone was added at the time of grinding. Liquid of leaves (aliquot) was taken in 50 ml volumetric flask and then absorbance was recorded at 662 nm (Abs) and 645 nm (Abs) respectively with the help of spectrophotometer (Gu *et al*., 2016).

The recorded values were substituted in the following formulas, for the estimation of chlorophyll content “a”, “b” and total chlorophyll.

3.6.2.1 Chlorophyll “a” (mg g^{-1})

$$= 12.7(A_{663}) - 2.69(A_{645}) \times \frac{V}{100 \times W}$$

3.6.2.2 Chlorophyll “b” (mg g^{-1})

$$= 22.9(A_{645}) - 4.68(A_{663}) \times \frac{V}{100 \times W}$$

3.6.2.3 Total chlorophyll (mg g^{-1})

$$= 20.2(A_{645}) + 8.02(A_{663}) \times \frac{V}{100 \times W}$$

Where, A_{663} and A_{645} are the absorbance measured from 663 nm and 645 nm, respectively. The spectrophotometer was adjusted to zero using the acetone/ethanol mixture.

3.6.3 Nutrient content analysis-

The methods used for estimating nutrient content in *Celtis australis* are as follows-

3.6.3.1 Nitrogen content-

Total nitrogen content in plant of *Celtis australis* was determined by Kjeldhal method. This method has following steps:

1) In a digestion tube, 0.5gram powdered sample of plants were digested with concentrated sulphuric acid (H_2SO_4) using constitution of digestant mixture and total nitrogen content was determined in percentage by Modified micro kjeldahl’s method (Jackson 1967).

2) Distillation and determination of total nitrogen in plant sample by titration (Humphries, 1956).

3.6.3.2 Nitrogen uptake

$$= \frac{\text{N \} \times \text{dry matter (kg/ha)}}{100}$$

3.6.3.3 Phosphors Content-

The composite sample of two plants were made from each plot and then 0.5 gm samples were taken from the composite sample and then digested in diacid mixture (4:1 of nitric: perchloric acid). The aliquot taken from the digest was used to develop yellow colour using solution of Ammonium vanadate and Ammonium molybdate. After development of yellow colour the absorbance was recorded at 420nm in the spectrophotometer (2375 double beam spectrophotometer) (Colwell, 1963).

3.6.3.4 Phosphorous uptake-

$$= \frac{\text{P \} \times \text{dry matter (kg/ha)}}{100}$$

3.6.3.5 Potassium Content-

For determination of potassium content in plant, the sample was digested in diacid mixture (4:1 of nitric: perchloric acid). The aliquot taken from the digest was used to determine the concentration of K from flame photometer (Black, 1965.)

3.6.3.6 Potassium uptake -

$$= \frac{\text{K \} \times \text{dry matter (kg/ha)}}{100}$$

3.6.4 Percent Plant survival (%) –

Percent Plant survival (%) was recorded by counting the total number of plants survived in each plot at 150 DAP.

$$= \frac{\text{No. of plants at the time of observation} \times 100}{\text{Total no. of plants}}$$

3.6.5. Statistical analysis–

The statistical analysis for all the treatments was done in factorial RBD with the help of OPSTAT software which is developed by O.P. Sheroan Professor Statistics, COBS & HCCS HAU, Hisar.

CHAPTER 4 EXPERIMENTAL RESULTS

The results of the investigation entitled **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"** are presented in this chapter**.** The experimental findings recorded during the course of investigation have been systematically described under various heads and sub heads.

4.1. Plant growth parameters

The data on growth parameters viz., shoot height (cm), root length (cm), collar diameter (cm), no. of leaves, white root regeneration and fresh and dry weight (g) of shoots, leaves and roots are presented under following heads.

4.1. 1. Shoot length (cm)

The perusal of data for shoot length presented in Table 4.1 indicates the significant effect of root pruning and nitrogen level on shoot length at different days (30, 60, 90, 120 and 150 days) after planting.

At 30 days after planting, the maximum length of shoot (73.42 cm) was observed in L_3 (12 cm pruning from the collar region) which was statistically at par with L_2 (6 cm pruning from the collar region) i.e., 71.59 cm whereas L_1 (control) recorded the minimum shoot length (66.60 cm). The nitrogen doses also had a significant effect on shoot length. The highest shoot length (75.52 cm) was obtained in N_3 (nitrogen 100kg/ha) which was statistically at par to N_4 (nitrogen 150kg/ha) i.e., 71.67 cm, while the minimum length of shoot (66.37 cm) was recorded in N_1 (control). The results further demonstrated the non-significant interactions between root pruning (L) and nitrogen (N) However, the maximum value for interaction (77.24 cm) was recorded under ($L_3 \times N_3$) (12 cm pruning from the collar region with nitrogen100kg/ha).

At 60 days after planting, the highest shoot length (74.68 cm) was noted in L_3 which was followed by L_2 (74.36 cm) and the lowest value for root pruning

(68.17 cm) was recorded in L_1 (control). The nitrogen doses also had significant effects on shoot length, The maximum shoot length was (77.11 cm) found in N_3 which was followed by N_4 i.e. (73.93 cm) whereas the minimum value (67.86 cm) was recorded under N_1 (control), Furthermore, the interaction (L×N) was found to be non-significant, However, the maximum value (79.27 cm) for interaction of both factors (L×N) was recorded under (L_2×N_3) treatment.

At 90 days after planting, the highest value for shoot length (81.15 cm) was obtained in L_3 which was statistically at par with L_2 (80.81 cm) while the minimum shoot length was recorded in L_1 (74.40 cm). Among the different nitrogen doses, the maximum value (83.68 cm) was recorded under N_3 which was statistically at par with N_4 (80.12 cm) whereas the minimum shoot length was observed in N_1 (74.34 cm) which was at par with N_2 (77.01 cm). Moreover, the interaction (L×N) was found to be non-significant for all the treatments. However, the maximum value (85.82 cm) was recorded under (L_2×N_3) while (L_1×N_1) recorded the minimum shoot length (69.00 cm).

At 120 days after planting, the highest value (89.10 cm) for root pruning length was found under L_3 treatment which was statistically at par with L_2 (88.70 cm) while L_1 recorded minimum shoot length (82.70 cm). For the different nitrogen doses, the highest shoot length (91.56 cm) was recorded in N_3 which was statistically at par with N_4 (87.98 cm) whereas the lowest value for shoot length (82.68 cm) was obtained under N_1 which was statistically at par with N_2 (85.11 cm). The result further demonstrate that non-significant interaction for all the treatments, however; the maximum value (93.61cm) was noted in (L_2×N_3) treatment while (L_1×N_1) recorded minimum (77.45cm) shoot length.

At 150 days after planting, the maximum value (90.72 cm) was noted in L_3 whereas the minimum shoot length (84.50 cm) was obtained under L_1.

Similarly for the nitrogen doses, the maximum value (93.27 cm) was recorded and N_3 which was followed by N_4 i.e. (89.70 cm) whereas the minimum value (84.34 cm) was noted under N_1. The interaction between the both factors the result showed non-significant interaction. However, the maximum value (95.17 cm) was recorded under ($L_3 \times N_3$) treatment while ($L_1 \times N_1$) recorded minimum shoot length (79.58 cm).

4.1.2. Root length (cm)

The data for root length depicted in Table 4.2 reveals that root pruning had significant effect on root length. At 30 days after planting, the maximum root length (29.16 cm) was observed in L_3 which was statistically at par with L_2 (22.99 cm) while it was significantly superior to L_1 (19.20 cm). The nitrogen application also had a significant effect on root length. The highest root length (25.94 cm) was obtained in N_3 which was statistically at par with N_4 (25.62 cm) while the minimum root length (21.57 cm) was obtained under N_1 (control). The interaction between root pruning and nitrogen doses (L×N) was found to be non-significant. The maximum value (33.40 cm) was obtained in ($L_3 \times N_4$) while the minimum value (17.86 cm) was obtained under ($L_1 \times N_1$).

At 60 days after planting, the highest value for root length (31.20 cm) was recorded under L_3 which was followed by L_2 (25.01 cm) whereas the lowest root length (21.25 cm) was noted in L_1 treatment. Under different nitrogen doses, the maximum root length of seedlings (27.98 cm) was noted in N_3 which was statistically at par to N_4 i.e. (27.66 cm) whereas, the minimum length of root (23.60 cm) was obtained in N_1 treatment. The interaction between the both factors was found non-significant. However, the maximum value for interaction (35.43 cm) was obtained under ($L_3 \times N_4$) whereas the minimum value (19.90 cm) was obtained under ($L_1 \times N_1$).

Table 4.1 :- The effect of root pruning length and nitrogen application on shoot length (cm) in *Celtis australis* at various growth stages.

Shoot length (cm)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	60.88	65.16	73.08	67.30	**66.60**	62.78	67.14	73.12	69.64	**68.17**	69.00	73.51	79.71	75.39	**74.40**	77.45	81.83	87.77	83.75	**82.70**	79.28	83.68	89.64	85.40	**84.50**
L_2	68.79	69.43	76.26	71.90	**71.59**	70.35	72.71	79.27	75.10	**74.36**	77.10	78.84	85.82	81.47	**80.81**	85.53	86.73	93.61	88.93	**88.70**	87.23	88.38	95.01	90.77	**90.34**
L_3	69.43	71.22	77.24	75.80	**73.42**	70.44	72.29	78.95	77.06	**74.68**	76.93	78.68	85.51	83.49	**81.15**	85.06	86.77	93.31	91.28	**89.10**	86.52	88.23	95.17	92.94	**90.72**
Mean	**66.37**	**68.60**	**75.52**	**71.67**		**67.86**	**70.71**	**77.11**	**73.93**		**74.34**	**77.01**	**83.68**	**80.12**		**82.68**	**85.11**	**91.56**	**87.98**		**84.34**	**86.76**	**93.27**	**89.70**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	5.35	6.18	N/S			5.07	5.86	N/S			5.36	6.19	N/S			5.31	6.13	N/S			5.31	6.13	N/S		

At 90 days after planting, the highest value for root length (35.22 cm) was recorded in L_3 which was followed by L_2 i.e. (29.03 cm) while it was significantly higher to L_1 (25.27 cm). Among the different doses, the highest value of root length (32.00 cm) was noted for N_3 which was statistically at par with N_4 i.e. (31.69 cm) while the minimum root length (27.61 cm) was reported in N_1 treatment. The interaction between the both factors was found to be non significant; however, the maximum value (39.44 cm) was recorded under ($L_3 \times N_4$) whereas the minimum value (23.92 cm) was observed in ($L_1 \times N_1$).

At 120 days after planting, the maximum value for root length (37.23 cm) was recorded in L_3 which was significantly more than to L_2 i.e. (31.04 cm) and L_1 (28.12 cm). Among the nitrogen doses, the highest value (34.81 cm) was recorded in N_3 which was statistically at par to N_4 i.e. (34.01 cm) while the minimum value (29.62 cm) was obtained under N_1 (control). The interaction between root pruning and nitrogen doses (L×N) was found to be non-significant. However, the highest (41.45 cm) and the lowest (25.93 cm) value for interaction was found under ($L_3 \times N_3$) and ($L_1 \times N_1$) respectively.

At 150 days after planting, the maximum root length (38.16 cm) was observed in L_3 which was followed by L_2 i.e. (32.55 cm) while the minimum root length was obtained under L_1 (29.02 cm). For the different nitrogen doses, the highest root length was (36.50 cm) was obtained in N_3 which was statistically at par with N_4 i.e. (34.92 cm) while the minimum root length (30.55 cm) was obtained under N_1 which was statistically at par with N_2 i.e. (31.00 cm). Further, the interaction between root pruning and nitrogen application was found to be non-significant however, the maximum value for interaction (42.40 cm) was obtained in ($L_3 \times N_3$) whereas the minimum value (26.84 cm) was recorded in ($L_1 \times N_1$).

Table 4.2 :- The effect of root pruning length and nitrogen application on root length (cm) in *Celtis australis* at various growth stages.

Root length (cm)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	17.86	18.53	21.56	18.86	**19.20**	19.90	20.57	23.60	20.91	**21.25**	23.92	24.59	27.62	24.96	**25.27**	25.93	26.60	30.31	29.63	**28.12**	26.84	27.53	31.18	30.54	**29.02**
L_2	19.86	21.23	26.28	24.59	**22.99**	21.84	23.27	28.32	26.63	**25.01**	25.84	27.29	32.34	30.65	**29.03**	27.85	29.30	32.69	34.35	**31.04**	28.82	30.21	35.91	35.26	**32.55**
L_3	27.00	26.26	29.98	33.40	**29.16**	29.05	28.32	32.02	35.43	**31.20**	33.07	32.34	36.04	39.44	**35.22**	35.07	34.35	41.45	38.05	**37.23**	36.00	35.26	42.40	38.97	**38.16**
Mean	**21.57**	**22.01**	**25.94**	**25.62**		**23.60**	**24.05**	**27.98**	**27.66**		**27.61**	**28.07**	**32.00**	**31.69**		**29.62**	**30.08**	**34.81**	**34.01**		**30.55**	**31.00**	**36.50**	**34.92**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	1.97	2.27	N/S			1.98	2.29	N/S			1.98	2.28	N/S			2.18	2.52	N/S			2.43	2.81	N/S		

4.1.3. Collar diameter (cm)

The data pertaining to the collar diameter in Table 4.3 indicates that the collar diameter was significantly affected by the root pruning length and application of nitrogen. At 30 days after planting, the maximum value of collar diameter (1.09 cm) was recorded in L_3 which was followed by L_2 i.e. (0.88 cm) while it was significantly superior over L_1 (0.65 cm). Among the nitrogen doses, the highest value of collar diameter (0.93 cm) was noted under N_3 treatment which was statistically at par to N_4 i.e. (0.90 cm) while the minimum (0.77 cm) was reported in N_1. The results further revealed that interaction effect of the both factors (L×N) was found to be significant for collar diameter. The maximum value of interaction for collar diameter (1.18 cm) was obtained with 12 cm root pruning and nitrogen @150kgN/ha (L_3×N_4) while the minimum value (0.57 cm) was found in (L_1×N_1) and (L_1×N_4).

At 60 days after planting, the highest value for collar diameter (1.13 cm) was recorded under L_3 which was followed by L_2 i.e. (0.92 cm) while the lowest collar diameter (0.69 cm) was noted in L_1 treatment. For the nitrogen application, the maximum root length of seedlings (0.98 cm) was noted in N_3 which was statistically at par to N_4 i.e. (0.95 cm) whereas, the minimum length of root (0.81cm) was obtained in N_1 treatment. The interaction between both factors (L×N) was found to be significant, where the maximum length (1.22 cm) was recorded in (L_3×N_4) while the minimum value (0.61 cm) was recorded in (L_1×N_1).

At 90 days after planting, L_3 recorded the maximum collar diameter (1.20 cm) which was followed by L_2 i.e. (1.01 cm) whereas L_1 showed a minimum value of collar diameter (0.78 cm). Among the different nitrogen application, N_3 recorded the highest collar diameter (1.06 cm) which was statistically at par to N_4 i.e. (1.03 cm) while the minimum value (0.90 cm) was obtained with the

treatment containing no application of nitrogen (N_1). The effect of interaction between length of root pruning and nitrogen doses (L×N) was found to be statistically significant with the highest value (1.28 cm) in (L_3×N_3) and the lowest value (0.70 cm) in (L_1×N_1) and (L_1×N_2).

At 120 days after planting, the maximum root length (1.26 cm) was recorded in L_3 which was followed by L_2 i.e. (1.10 cm) while the minimum collar diameter was obtained under L_1 i.e. (0.86 cm). For the nitrogen doses, the highest value of collar diameter (1.20 cm) was noted in N_3 which was at par with N_4 i.e. (1.13 cm) while the minimum value (0.91 cm) was obtained in N_1. The interaction between length of root pruning and nitrogen doses (L×N) was found to be significant with the highest value (1.36 cm) in (L_3×N_3) and the lowest value in (L_1×N_1) (0.71 cm) respectively.

At 150 days after planting, the highest collar diameter (1.36 cm) was observed in L_3 which was followed by L_2 i.e. (1.20 cm) while the lowest collar diameter (0.96 cm) was observed in L_1. For nitrogen application, the highest root length (1.30 cm) was obtained in N_3 followed by N_4 i.e. (1.23 cm) while the minimum (1.01 cm) was obtained in N_1. The interaction effect of length of root pruning and nitrogen doses (L×N) was found to be significant for collar diameter with maximum (1.46 cm) in (L_3×N_3) and the minimum (0.81 cm) in (L_1×N_1) and also found statistically significant to all other treatments.

4.1.4 Number of leaves

A close perusal for number of leaves is presented in Table 4.4 which indicates that root pruning had significant effect on the number of leaves. The maximum number of leaves (108.25) was recorded in L_3 which was statistically at par with L_2 i.e. (97.16) while the minimum number of leaves (69.95) was

Table 4.3 :- The effect of root pruning length and nitrogen application on collar diameter (cm) in *Celtis australis* at various growth stages.

Collar diameter (cm)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.57	0.62	0.86	0.57	**0.65**	0.61	0.66	0.90	0.62	**0.69**	0.70	0.70	0.99	0.75	**0.78**	0.71	0.75	1.11	0.86	**0.86**	0.81	0.85	1.21	0.96	**0.96**
L_2	0.71	1.06	0.80	0.96	**0.88**	0.75	1.10	0.84	1.00	**0.92**	0.84	1.09	0.93	1.19	**1.01**	0.85	1.14	1.12	1.27	**1.10**	0.95	1.24	1.22	1.37	**1.20**
L_3	1.02	1.02	1.15	1.18	**1.09**	1.06	1.06	1.19	1.22	**1.13**	1.15	1.22	1.28	1.15	**1.20**	1.16	1.27	1.36	1.26	**1.26**	1.26	1.37	1.46	1.36	**1.36**
Mean	**0.77**	**0.90**	**0.93**	**0.90**		**0.81**	**0.94**	**0.98**	**0.95**		**0.90**	**1.00**	**1.06**	**1.03**		**0.91**	**1.05**	**1.20**	**1.13**		**1.01**	**1.15**	**1.30**	**1.23**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.05	0.06	0.10			0.05	0.06	0.10			0.05	0.05	0.10			0.04	0.04	0.08			0.04	0.04	0.08		

obtained in L_1. The different nitrogen doses also had significant effects on the number of leaves.

The highest number of leaves (108.25) was obtained in N_3 which was at par to N_2 i.e. (104.11) while the minimum length of shoot (58.33) was recorded in N_1. The result further showed the significant effects of interaction between both the factors (L×N). The maximum value for interaction of both factors (L×N) was recorded under (L_2×N_2) i.e. (149.33) whereas it was minimum in (L_1×N_1) i.e. (40.00).

At 60 days after planting, the maximum number of leaves (110.25) was recorded in L_3 which was statistically at par with L_2 i.e. (99.16) while the minimum number of leaves (80.75) was obtained in L_1. The nitrogen doses also had significant effects on the number of leaves. The highest number of leaves was obtained in N_3 (113.27) which were statistically at par to N_2 (109.44) while the minimum number of leaves (63.66) was recorded in N_1 (control). The maximum value for interaction between both factors (L×N) was recorded under (L_2×N_2) i.e. (151.33) and the minimum in (L_1×N_1) i.e. (52.00) which was found to be significant among all the treatments.

At 90 days after planting, the maximum number of leaves (114.25) was recorded in L_3 which was statistically at par with L_2 i.e. (103.16) and the minimum number of leaves (84.75) was obtained in L_1. Nitrogen doses also had significant effects on number of leaves. The highest number of leaves (117.27) was obtained in N_3 which was statistically at par to N_2 i.e. (113.44) while the minimum length of shoot (67.66) was recorded in N_1. The maximum value for interaction of both factors (L×N) was recorded under (L_2×N_2) i.e. (155.33) and the minimum in (L_1×N_1) i.e. (56.00) which was found significant to all other treatments.

At 120 days after planting, the maximum number of leaves (120.41) was recorded in L_3 which was statistically at par with L_2 i.e. (109.16) whereas the minimum number of leaves (93.25) was obtained in L_1 (control). For the nitrogen doses, the highest number of leaves (123.27) was obtained in N_3 which was statistically at par to N_2 (122.70) while the minimum length of shoot (73.88) was recorded in N_1. The result further showed the significant effect of interaction between both the factors. The maximum value for interaction of both factors (L×N) was recorded under (L_2×N_2) (161.33) while the minimum in (L_1×N_1) (62.00).

At 150 days after planting, the maximum number of leaves (121.41) was recorded in L_3 which was statistically at par with L_2 i.e. (110.16) while the minimum number of leaves (94.25) was obtained in L_1. Nitrogen doses also had significant effects on number of leaves. The highest number of leaves (124.27) was obtained in N_3 which was statistically at par with N_2 i.e. (123.77) while the minimum length of shoot (74.88) was recorded in N_1. The interaction between both the factors was also found to be significant. The maximum value for interaction of both factors (L×N) was recorded under (L_2×N_2) i.e. (162.33) and while it was minimum in (L_1×N_1) i.e. (63.00).

4.1.5. Fresh weight of shoot (g)

It's clearly evident from the perusal data presented in Table 4.5 indicates the significant effects of root pruning and nitrogen level on fresh weight of shoot at 30, 60, 90, 120 and 150 days after planting.

At 30 days after planting, the maximum fresh weight of shoot (6.99 g) was recorded in L_3 which was statistically at par to L_2 i.e. (6.35 g) while the minimum fresh weight of shoot (5.96 g) was obtained in L_1. The nitrogen doses also had a significant effect on fresh weight. The highest fresh weight of shoot (7.47 g) was

Table 4.4 :- The effect of root pruning length and nitrogen application on no. of leaves in *Celtis australis* at various growth stages.

No. of leaves

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	40.00	62.00	111.33	66.50	**69.95**	52.00	74.00	123.00	74.00	**80.75**	56.00	78.00	127.00	78.00	**84.75**	62.00	94.00	133.00	84.00	**93.25**	63.00	95.00	134.00	85.00	**94.25**
L_2	66.83	149.333	83.66	88.83	**97.16**	68.83	151.33	85.66	90.83	**99.16**	72.83	155.33	89.66	94.83	**103.16**	78.83	161.33	95.66	100.83	**109.16**	79.83	162.33	96.66	101.83	**110.16**
L_3	68.16	101.000	129.16	134.66	**108.25**	70.16	103.00	131.16	136.66	**110.25**	74.16	107.00	135.17	140.66	**114.25**	80.83	113.00	141.16	146.66	**120.41**	81.83	114.00	142.16	147.66	**121.41**
Mean	**58.33**	**104.111**	**108.05**	**96.66**		**63.66**	**109.44**	**113.27**	**100.50**		**67.66**	**113.44**	**117.27**	**104.50**		**73.88**	**122.7**	**123.27**	**110.50**		**74.88**	**123.77**	**124.27**	**111.50**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	17.67	20.40	35.33			17.30	20.02	34.68			17.34	20.02	34.68			17.73	20.47	35.46			17.73	20.47	35.46		

reported in N_3 treatment which was statistically at par to N_4 treatment (6.86 g) while the minimum (4.88 g) value for fresh weight of shoot was recorded in N_1 treatment. The results further demonstrated the significant interaction between root pruning (L) and nitrogen doses (N). However, the maximum fresh weight for interaction (9.26 g) was recorded under ($L_3 \times N_4$) while the minimum fresh weight (3.87 g) was recorded in ($L_3 \times N_1$).

At 60 days after planting, the highest fresh weight of shoot (11.36 g) was recorded in L_3 which was statistically at par to L_2 i.e. (10.80 g) while the minimum fresh weight of shoot (8.57 g) was obtained in L_1. The nitrogen doses also had a significant effect on the fresh weight of shoot. The highest fresh weight of shoot (11.39 g) was recorded in N_3 which was at par to N_4 treatment (10.83 g) while the minimum shoot length (8.79 g) was noted under N_1. The maximum value for interaction between both factors (L×N) was recorded under ($L_2 \times N_3$) (13.93 g) while the minimum fresh weight of shoot (8.10 g) was recorded in ($L_2 \times N_1$).

At 90 days after planting, the maximum fresh weight of shoot (14.54 g) was recorded in L_3 which was statistically at par to L_2 i.e. (13.80 g) while the minimum fresh weight of shoot (11.42 g) was recorded in L_1 treatment. Among the nitrogen doses, the highest fresh weight of shoot (14.44 g) was reported in N_3 treatment which was statistically at par to N_4 treatment (13.79 g) while the minimum value for fresh weight of shoot (11.61 g) was recorded in N_1. The interaction effect of both factors was also found significant and the maximum value for shoot fresh weight (17.00 g) was observed in ($L_2 \times N_3$) treatment and the minimum fresh weight of shoot (10.83 g) was recorded in ($L_2 \times N_1$).

At 120 days after planting, the maximum fresh weight of shoot (16.73 g) was observed in L_3 which was statistically at par with L_2 (15.90 g) and the

minimum fresh weight of shoot (13.52 g) was obtained in L_1. Among the nitrogen doses, the highest fresh weight of shoot (16.54 g) was obtained in N_3 which was statistically at par to N_4 i.e. (15.99 g) while the minimum fresh weight of shoot (13.71 g) was recorded in N_1. The interaction effect of both factors was also found significant and the maximum value for shoot fresh weight (19.10 g) was recorded under ($L_2 \times N_3$) while the minimum fresh weight of shoot (12.93 g) was recorded in ($L_2 \times N_1$) which was found significant to all other treatments.

At 150 days after planting, the maximum fresh weight of shoot (17.74 g) was recorded in L_3 which was at par with L_2 (16.83 g) and the minimum fresh weight of shoot (14.53 g) was obtained in L_1 (control). Among the nitrogen doses, the highest fresh weight of shoot (17.55 g) was obtained in N_3 which was at par to N_4 (16.89 g) while the minimum fresh weight of shoot (14.72 g) was observed in N_1. The maximum (20.11 g) value for interaction of both factors (L×N) was recorded under ($L_2 \times N_3$) and the minimum value (13.94 g) was noted in ($L_2 \times N_1$) which was found significant to all other treatments.

4.1.6. Dry weight of shoot (g)

The data related to dry weight of shoot as influenced by the effect of root pruning are presented in Table 4.6. Whereas, the root pruning had a significant effect on dry weight of shoot. At 30 days after planting, the highest dry weight of shoot (3.76 g) was observed in L_3 which was followed by L_2 i.e. (2.80 g) while the minimum fresh weight of shoot (2.79 g) was recorded in L_1 and nitrogen doses also had a significant effect on dry weight of shoot and among the nitrogen doses, the maximum dry weight of shoot (3.72 g) was noticed in N_3 which was followed by N_4 i.e. (3.28 g) while the minimum dry weight of shoot (2.51 g) was noted in N_1 (control). The interaction effect due to the root pruning length and application of nitrogen showed significant result among different combination whereas, the

Table 4.5 :- The effect of root pruning length and nitrogen application on fresh weight of shoot in *Celtis australis* at various growth stages.

Fresh weight of shoot (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	5.16	6.12	7.15	5.42	**5.96**	8.51	8.26	8.90	8.63	**8.57**	11.24	11.31	11.89	11.27	**11.42**	13.34	13.41	13.99	13.34	**13.52**	14.35	14.42	15.00	14.35	**14.53**
L_2	5.60	6.26	7.63	5.90	**6.35**	8.10	10.54	13.93	10.63	**10.80**	10.83	13.59	17.00	13.79	**13.80**	12.93	15.69	19.10	15.89	**15.90**	13.94	16.70	20.11	16.57	**16.83**
L_3	3.87	7.20	7.63	9.26	**6.99**	9.77	11.09	11.36	13.24	**11.36**	12.77	14.67	14.42	16.33	**14.54**	14.87	16.77	16.52	18.76	**16.73**	15.88	17.78	17.53	19.77	**17.74**
Mean	**4.88**	**6.53**	**7.47**	**6.86**		**8.79**	**9.96**	**11.39**	**10.83**		**11.61**	**13.19**	**14.44**	**13.79**		**13.71**	**15.29**	**16.54**	**15.99**		**14.72**	**16.30**	**17.55**	**16.89**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.70	0.80	1.40			0.79	0.92	1.59			0.78	0.90	1.56			0.80	0.92	1.59			0.80	0.93	1.61		

maximum dry weight of shoot (4.78 g) was recorded in ($L_3 \times N_4$) and the minimum dry weight of shoot (2.32 g) was noticed in ($L_2 \times N_1$).

At 60 days after planting, the maximum dry weight of shoot (5.81 g) was observed in L_3 followed by L_2 (4.85 g) while the minimum dry weight of shoot (4.92 g) was recorded in L_1 and among the nitrogen doses, the maximum dry weight of shoot (5.77 g) was noticed in N_3 which was followed by N_4 i.e. (5.33 g) and while the minimum dry weight of shoot (4.67 g) was registered in N_1 (control). The result further demonstrates the significant effect of interaction between both the factors (L×N). The maximum dry weight of shoot (6.83 g) was recorded in ($L_3 \times N_4$) while the minimum dry weight of shoot (4.37 g) was noticed in ($L_2 \times N_1$).

At 90 days after planting, the maximum dry weight of shoot (6.84 g) was observed in L_3 which was followed by L_2 i.e. (5.95 g) while the minimum dry weight of shoot (5.88 g) was observed in L_1 and among the nitrogen doses, the maximum dry weight of shoot (6.80 g) was noticed in N_3 which was followed by N_4 i.e. (6.36 g) while the minimum dry weight of shoot (5.70 g) was registered in N_1. The interaction between both factors (L×N) was found to be significant whereas the maximum dry weight of shoots (7.87 g) was recorded in ($L_3 \times N_4$) and the minimum dry weight of shoot (5.40 g) was noticed in ($L_1 \times N_1$).

At 120 days after planting, the maximum dry weight of shoot (7.86 g) was observed in L_3 followed by L_2 i.e. (6.97 g) while the minimum dry weight of shoot (6.90 g) was recorded in L_1. Among the nitrogen doses, the maximum dry weight of shoot (7.82 g) was recorded in N_3 which was followed by N_4 i.e. (7.38 g) and the minimum dry weight of shoot (6.72 g) was registered in N_1.The interaction effect due to the root pruning length and application of nitrogen showed significant result among the different combination whereas, the maximum

dry weight of shoots (8.89 g) was recorded in ($L_3 \times N_4$) while the minimum dry weight of shoot was (6.42 g) noticed in ($L_1 \times N_1$).

At 150 days after planting, the maximum dry weight of shoot (8.35 g) was observed in L_3 which was followed by L_2 i.e. (7.39 g) while the minimum dry weight of shoot (7.28 g) was recorded in L_1. Among the nitrogen doses, the maximum dry weight of shoot (8.39 g) was noticed at in N_3 which was followed by N_4 i.e. (7.68 g) while the minimum dry weight of shoot (7.10 g) was registered in N_1 (control). The interaction between length of root pruning and nitrogen doses (L×N) was found to be significant with maximum dry weight of shoots (9.20 g) in ($L_3 \times N_4$) and the minimum dry weight of shoot (6.82 g) in ($L_1 \times N_1$).

4.1.7. Fresh weight of root (g)

A close perusal of fresh weight of root is presented in Table 4.7 which denotes the root pruning had a significant effect on the fresh weight of roots. At 30 days after planting, the maximum fresh weight of root (5.15 g) was observed in L_3 over rest of the treatments and followed by L_2 i.e. (4.96 g) while the minimum fresh weight of root (3.70 g) was observed in L_1. Among the nitrogen doses, the maximum fresh weight of root (5.34 g) was recorded in N_3 which was followed by N_4 i.e. (4.95 g) while the minimum fresh weight of root (4.05 g) was reported in N_1. The result further showed the significant effect of interaction between both the factors (L×N). The maximum fresh weight of roots (7.24 g) for interaction was observed in ($L_3 \times N_3$) while the minimum fresh weight of root (3.28 g) was reported in ($L_1 \times N_3$).

At 60 days after planting, the maximum fresh weight of root (6.99 g) was registered in L_3 which was at par with L_2 i.e. (6.97 g) while the minimum fresh weight of root (5.71 g) was reported in L_1 (control) and for the nitrogen doses, the maximum fresh weight of root (7.36 g) was recorded in N_3 which was followed

Table 4.6 :- The effect of root pruning length and nitrogen application on dry weight of shoot in *Celtis australis* at various growth stages.

Dry weight of shoot (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	2.41	2.49	3.75	2.51	**2.79**	4.79	4.54	5.80	4.56	**4.92**	5.40	5.54	6.94	5.64	**5.88**	6.42	6.56	7.96	6.66	**6.90**	6.82	7.06	8.29	6.96	**7.28**
L_2	2.32	2.46	3.86	2.56	**2.80**	4.37	4.51	5.91	4.61	**4.85**	5.82	5.57	6.83	5.59	**5.95**	6.84	6.59	7.85	6.61	**6.97**	7.09	7.06	8.50	6.89	**7.39**
L_3	2.81	3.90	3.56	4.78	**3.76**	4.86	5.95	5.61	6.83	**5.81**	5.89	6.98	6.64	7.87	**6.84**	6.91	8.00	7.66	8.89	**7.86**	7.39	8.40	8.39	9.20	**8.35**
Mean	**2.51**	**2.95**	**3.72**	**3.28**		**4.67**	**5.00**	**5.77**	**5.33**		**5.70**	**6.03**	**6.80**	**6.36**		**6.72**	**7.05**	**7.82**	**7.38**		**7.10**	**7.51**	**8.39**	**7.68**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.49	0.57	0.99			0.51	0.59	1.03			0.51	0.59	1.03			0.51	0.59	1.03			0.52	0.60	1.05		

by N_2 i.e. (6.85 g) while the minimum fresh weight of root (5.96 g) was reported in N_1. The interaction of both factor (L×N) showed significant variation and the maximum value for root fresh weight (9.25 g) was observed in (L_3×N_3) treatment and the minimum fresh weight of root (5.29 g) was reported in (L_1×N_3).

At 90 days after planting, the maximum fresh weight of root (9.01 g) was registered in L_3 and L_2 while the minimum fresh weight of root (7.73 g) was observed in L_1 (control) and among the nitrogen doses, the maximum fresh weight of root (9.38 g) was recorded in N_3 which was followed by N_2 (8.87 g) while the minimum fresh weight of root (8.02 g) was reported in N_1 (control).The interaction of both factor (L×N) showed significant variation and the maximum value for root fresh weight (11.27 g) was observed in (L_2×N_3) while the minimum fresh weight of root (7.31 g) was reported in (L_1×N_3).

At 120 days after planting, the maximum fresh weight of root (10.02 g) was registered in L_3 over rest of the treatments and which was at par with L_2 (9.94 g) while the minimum fresh weight of root (8.74 g) was recorded in L_1 (control). Among the nitrogen doses, the maximum fresh weight of root (10.39 g) was recorded in N_3 which was followed by N_2 i.e. (9.77 g) while the minimum fresh weight of root (9.03 g) was reported in N_1 (control). The interaction between both factor (L×N) showed significant variation and the maximum value for root fresh weight (12.28 g) was observed in (L_3×N_3) treatment while the minimum fresh weight of root (8.32 g) was reported in (L_1×N_3).

At 150 days after planting, the maximum fresh weight of root (10.95 g) was registered in L_3 and L_2 while the minimum fresh weight of root (9.75 g) was recorded in L_1 (control). Among the nitrogen doses, the maximum fresh weight of root (11.40 g) was recorded in N_3 which was followed by N_2 i.e. (10.67 g) while the minimum fresh weight of root (10.04 g) was reported in N_1 (control). The

Table 4.7 :- The effect of root pruning length and nitrogen application on fresh weight of root in *Celtis australis* at various growth stages.

Fresh weight of root (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	3.55	3.40	3.28	4.54	**3.70**	5.46	6.55	5.29	5.56	**5.71**	7.48	8.57	7.31	7.58	**7.73**	8.49	9.58	8.32	8.59	**8.74**	9.50	10.59	9.33	9.60	**9.75**
L_2	4.10	4.49	5.51	5.73	**4.96**	6.50	7.74	7.52	6.10	**6.97**	7.96	8.27	11.27	8.54	**9.01**	9.64	10.44	10.55	9.13	**9.94**	9.98	9.96	13.29	10.56	**10.95**
L_3	4.51	4.26	7.24	4.58	**5.15**	5.94	6.26	9.25	6.52	**6.99**	8.63	9.76	9.54	8.12	**9.01**	8.97	9.28	12.28	9.55	**10.02**	10.65	11.45	11.56	10.14	**10.95**
Mean	**4.05**	**4.07**	**5.34**	**4.95**		**5.96**	**6.85**	**7.36**	**6.06**		**8.02**	**8.87**	**9.38**	**8.08**		**9.03**	**9.77**	**10.39**	**9.09**		**10.04**	**10.67**	**11.40**	**10.10**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.80	0.93	1.61			0.83	0.95	1.65			0.82	0.95	1.65			0.87	1.01	1.75			0.87	1.00	1.74		

interaction between both factors (L×N) was found to be significant with the maximum value (11.56 g) in (L_3×N_3) and the minimum (9.33 g) in (L_1×N_3).

4.1.8. Dry weight of root (g)

The data related to dry weight of root as influenced by the root pruning and nitrogen application are presented in Table 4.8. At 30 days after planting, the root pruning had a significant effect on dry weight of root and the highest dry weight of root (2.54 g) was observed in L_3 followed by L_2 i.e. (1.88 g) while the minimum dry weight of root (1.75 g) was observed in L_1 (control) and nitrogen doses also had a significant effect on dry weight of root and among the nitrogen doses, the maximum dry weight of root (2.45 g) was noticed in N_3 which was followed by N_4 i.e. (2.39 g) while the minimum dry weight of root (1.40 g) was observed in N_1 (control). The interaction effect due to the root pruning length and application of nitrogen showed significant result among different combination and the maximum dry weight of root (2.94 g) was recorded in (L_3×N_3) and (L_3×N_4) while the minimum dry weight of root (1.04 g) was recorded in (L_1×N_1).

At 60 days after planting, the maximum dry weight of root (3.72 g) was observed in L_3 which was followed by L_2 i.e. (3.38 g) while the minimum fresh weight of root (2.47 g) was recorded in L_1 (control) and among the nitrogen doses, the maximum dry weight of root (3.54 g) was noticed in N_3 which was followed by N_4 i.e. (3.30 g) while the minimum dry weight of root (2.68 g) was recorded in N_1 (control).The interaction effect of length of root pruning and nitrogen doses (L×N) was found to be significant and the maximum dry weight of root (4.91 g) was recorded in (L_3×N_3) and the minimum dry weight of root (2.06 g) was noticed in (L_1×N_1).

At 90 days after planting, the maximum dry weight of root (5.66 g) was observed in L_3 followed by L_2 i.e. (5.46 g) while the minimum dry weight of root

(4.68 g) was reported in L_1 (control) and among the nitrogen doses, the maximum dry weight of root (5.46 g) was noticed in N_3 which was followed by N_4 i.e. (5.41 g) and the minimum dry weight of root (4.96 g) was reported in N_1 (control). The interaction (L×N) was found to be significant for all the treatment. However, the maximum dry weight of root (6.63 g) was recorded in (L_3×N_3) and the minimum dry weight of root (4.24 g) was noticed in (L_1×N_3).

At 120 days after planting, the maximum dry weight of shoot (6.68 g) was observed in L_3 followed by L_2 i.e. (6.48 g) while the minimum dry weight of root (5.70 g) was recorded in L_1 (control) and among the nitrogen doses, the maximum dry weight of root (6.48 g) was noticed in N_3 which was followed by N_4 i.e. (6.43 g) while the minimum dry weight of root (5.98 g) was registered in N_1 (control). For the interaction effect due to the root pruning length and application of nitrogen showed significant result and the maximum dry weight of root (7.65 g) was recorded in (L_3×N_3) and the minimum dry weight of root (5.34 g) was noticed in (L_1×N_1).

At 150 days after planting, the maximum dry weight of root (7.64 g) was observed in root L_3 followed by L_2 i.e. (7.34 g) while the minimum dry weight of root (6.34 g) was observed in L_1 (control) and among the nitrogen doses, the maximum dry weight of root (7.38 g) was noticed in N_3 which was followed by N_4 i.e. (7.35 g) while the minimum dry weight of root (6.38 g) was recorded in N_1 (control). The interaction between root pruning length and nitrogen doses (L×N) was found to be significant and the maximum dry weight of root (8.95 g) was recorded in root (L_3×N_3) while the minimum dry weight of root (5.78 g) was noticed in (L_1×N_1).

4.1.9. Fresh weight of leaves (g)

The data for fresh weight of leaves depicted in Table 4.9 reveals that root

Table 4.8 :- The effect of root pruning length and nitrogen application on dry weight of root in *Celtis australis* at various growth stages.

Dry weight of root (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	1.04	1.68	3.06	1.19	**1.75**	2.06	2.37	2.39	3.05	**2.47**	4.32	5.00	4.24	5.15	**4.68**	5.34	6.02	5.26	6.17	**5.70**	5.78	6.82	6.20	6.56	**6.34**
L_2	1.26	1.90	1.34	3.03	**1.88**	3.24	3.70	3.34	3.26	**3.38**	5.64	5.06	5.50	5.64	**5.46**	6.66	6.08	6.52	6.66	**6.48**	7.26	7.26	7.00	7.86	**7.34**
L_3	1.91	2.40	2.94	2.94	**2.54**	2.73	3.64	4.91	3.59	**3.72**	4.92	5.66	6.63	5.44	**5.66**	5.94	6.68	7.65	6.46	**6.68**	6.10	7.86	8.95	7.64	**7.64**
Mean	**1.40**	**1.99**	**2.45**	**2.39**		**2.68**	**3.23**	**3.54**	**3.30**		**4.96**	**5.24**	**5.46**	**5.41**		**5.98**	**6.26**	**6.48**	**6.43**		**6.38**	**7.31**	**7.38**	**7.35**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.44	0.51	0.89			0.49	0.57	0.98			0.32	0.37	0.32			0.32	0.37	0.65			0.48	0.55	0.96		

pruning had a significant effect on leaves fresh weight. At 30 days after planting, the maximum fresh weight of leaves (4.21 g) was observed in L_3 over rest of the treatments which was followed by L_2 (3.35 g) while the minimum fresh weight of leaves (3.21 g) was recorded in L_1 (control). The nitrogen doses also had a significant effect on leaves fresh weight. Among the nitrogen doses, the maximum fresh weight of leaves (4.61 g) was recorded in N_3 which was followed by N_4 i.e. (3.63 g) while the minimum fresh weight of leaves (2.69 g) was reported in N_1 (control). The interaction between root pruning and nitrogen doses (L×N) was found to be significant. The maximum fresh weight of leaves (5.50 g) was observed in (L_3×N_2) and the minimum fresh weight of leaves (1.78 g) was reported in (L_1×N_2).

At 60 days after planting, the maximum fresh weight of leaves (6.25 g) was observed in L_3 followed by L_2 i.e. (5.70 g) while the minimum fresh weight of leaves (4.94 g) was found in L_1 (control) and among the nitrogen doses, the maximum fresh weight of leaves (6.26 g) was recorded in N_3 which was followed by N_4 i.e. (5.68 g) while the minimum fresh weight of leaves (5.02 g) was reported in N_1 (control). The interaction of both factor (L×N) showed significant variation and the maximum fresh weight of leaves (7.75 g) was observed in (L_3×N_2) treatment and the minimum fresh weight of leaves (3.49 g) was reported in (L_1×N_2).

At 90 days after planting, the maximum fresh weight of leaves (7.25 g) was observed in L_3 which was followed by L_2 i.e. (6.94 g) while the minimum fresh weight of leaves (5.78 g) in L_1 (control) and among the nitrogen doses, the maximum fresh weight of leaves (7.26 g) was recorded in N_3 which was followed by N_4 i.e. (7.00 g) while the minimum fresh weight of leaves (5.80 g) was recorded in N_1 (control). The interaction of both factor (L×N) showed significant variation and the maximum value for fresh weight of leaves (8.75 g) was observed

in ($L_3 \times N_2$) while the minimum fresh weight of leaves (4.05 g) was reported in ($L_1 \times N_1$).

At 120 days after planting, the maximum fresh weight of leaves (8.26 g) was observed in L_3 which was followed by L_2 i.e. (7.95 g) while the minimum fresh weight of leaves (6.79 g) was recorded in L_1 (control) and among the nitrogen doses, the maximum fresh weight of leaves was (8.27 g) observed in N_3 which was followed by N_4 i.e. (8.01 g) while the minimum fresh weight of leaves (6.81 g) was reported in N_1 (control). The results further demonstrated the significant variation for all the treatment and the maximum fresh weight of leaves (9.76 g) was observed in ($L_3 \times N_2$) and the minimum fresh weight of leaves (5.06 g) was reported in ($L_1 \times N_1$).

At 150 days after planting, the maximum fresh weight of leaves (9.25 g) was observed in L_3 which was followed by L_2 i.e. (8.94 g) while the minimum fresh weight of leaves (7.77 g) was recorded in control (L_1). For the different nitrogen doses, the maximum fresh weight of leaves (9.26 g) was recorded in N_3 which was followed by N_4 i.e. (8.99 g) while the minimum fresh weight of leaves (7.80 g) was reported in N_1 (control). The interaction of both factor (L×N) showed significant variation and the maximum fresh weight of leaves (10.75 g) was observed in ($L_3 \times N_2$) and the minimum fresh weight of leaves (6.05 g) was reported in ($L_1 \times N_1$).

4.1.10. Dry weight of leaves (g)

The data pertaining to dry weight of leaves in Table 4.10 indicates the dry weight of leaves significantly affected by the root pruning length and nitrogen application. At 30 days after planting, the highest dry weight of leaves (0.66 g) was observed in L_3 which was followed by L_2 i.e. (0.58 g) while the minimum dry weight of leaves (0.44 g) was observed in L_1 (control) and for the different

Table 4.9 :- The effect of root pruning length and nitrogen application on dry weight of root in *Celtis australis* at various growth stages.

Fresh weight of leaves (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	2.08	1.78	4.83	4.15	**3.21**	3.72	3.49	6.33	6.25	**4.94**	4.05	4.49	7.33	7.25	**5.78**	5.06	5.50	8.34	8.26	**6.79**	6.05	6.49	9.33	9.23	**7.77**
L_2	3.33	3.02	4.87	2.20	**3.35**	6.96	5.46	6.20	4.17	**5.70**	7.96	6.46	7.20	6.13	**6.94**	8.97	7.47	8.21	7.14	**7.95**	9.97	8.46	9.20	8.13	**8.94**
L_3	2.66	5.50	4.15	4.53	**4.21**	4.40	7.75	6.25	6.62	**6.25**	5.40	8.75	7.25	7.62	**7.25**	6.41	9.76	8.26	8.63	**8.26**	7.40	10.75	9.25	9.62	**9.25**
Mean	**2.69**	**3.43**	**4.61**	**3.63**		**5.02**	**5.56**	**6.26**	**5.68**		**5.80**	**6.56**	**7.26**	**7.00**		**6.81**	**7.57**	**8.27**	**8.01**		**7.80**	**8.56**	**9.26**	**8.99**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.74	0.86	1.49			0.71	0.82	1.42			0.74	0.86	1.48			0.74	0.86	1.48			0.74	0.86	1.49		

nitrogen doses, the maximum dry weight of leaves (0.68 g) was noticed in N_3 which was followed by N_4 i.e. (0.58 g) while the minimum dry weight of leaves (0.44 g) was registered in N_1 (control). The interaction effect due to the root pruning length and application of nitrogen showed significant result among different combination and the maximum dry weight of leaves (0.87 g) was recorded in ($L_2 \times N_3$) and ($L_1 \times N_3$) and the minimum dry weight of leaves (0.21 g) was recorded in ($L_1 \times N_1$).

At 60 days after planting, the maximum dry weight of leaves (2.05 g) was observed in L_3 followed by L_2 i.e. (1.60 g) while the minimum dry weight of leaves (1.27 g) was noticed in L_1 (control) and among the nitrogen doses, the maximum dry weight of leaves (2.23 g) was noticed in N_3 which was followed by N_4 i.e. (1.58 g) while the minimum dry weight of leaves (1.30 g) was registered in N_1 (control). The interaction between length of root pruning and application of nitrogen (L×N) was found to be significant with the maximum dry weight of leaves (3.07 g) was recorded in ($L_2 \times N_3$) and minimum dry weight of leaves (1.05 g) was recorded in ($L_2 \times N_1$).

At 90 days after planting, the highest dry weight of leaves (3.47 g) was observed in L_3 which was followed by L_2 i.e. (2.83 g) while the minimum dry weight of leaves (2.54 g) was recorded in L_1 (control) and among the nitrogen doses, the maximum dry weight of leaves (3.45 g) was noticed in N_3 which was statistically at par with N_4 i.e. (3.15 g) while the minimum dry weight of leaves (2.53 g) was registered in N_1 (control). The result further indicates the significant interaction for all the treatment However; the maximum dry weight of leaves (3.97 g) was recorded in ($L_3 \times N_2$) and the minimum dry weight of leaves (1.31 g) was noted in ($L_1 \times N_2$).

At 120 days after planting, the maximum dry weight of leaves (3.91 g) was recorded in L_3 which was statistically at par with L_2 i.e. (3.50 g) while the minimum dry weight of leaves (3.16 g) was recorded in L_1 (control). For the different nitrogen doses, the maximum dry weight of leaves (3.88 g) was noticed in N_3 which was statistically at par with N_4 i.e. (3.77 g) while the minimum dry weight of leaves (3.11 g) was registered in N_1 (control). The interaction between length of root pruning and nitrogen application (L×N) was found to be significant with the maximum value (4.66 g) in ($L_1 \times N_4$) and minimum value (2.00 g) in ($L_1 \times N_2$).

At 150 days after planting, the highest dry weight of leaves (5.08 g) was observed in L_3 followed by L_2 i.e. (4.62 g) while the minimum dry weight of leaves (4.25 g) was recorded in L_1 (control). For the nitrogen doses, the maximum dry weight of leaves (5.04 g) was noticed in N_3 which was followed by N_4 i.e. (4.87 g) while the minimum dry weight of leaves (4.22 g) was registered in N_1 (control). The results further showed the significant effect of interaction between root pruning length and application of nitrogen (L×N). The maximum dry weight of leaves (5.80 g) was recorded in ($L_1 \times N_4$) while the minimum dry weight of leaves (3.07 g) was recorded in ($L_1 \times N_2$).

4.2. Physiological parameters

The data on physiological parameters viz. white root regeneration, survival percent (%) and chlorophyll content ‘a’, ‘b’ and total chlorophyll are presented under separate heads:

4.2.1. White root regeneration

The perusal of data for white root regeneration presented in Table 4.11

Table 4.10 :- The effect of root pruning length and nitrogen application on dry weight of leaves in *Celtis australis* at various growth stages.

Dry weight of leaves (g)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.21	0.36	0.87	0.33	**0.44**	1.26	1.27	1.34	1.24	**1.27**	1.64	1.31	3.34	3.90	**2.54**	2.33	2.00	3.66	4.66	**3.16**	3.36	3.07	4.79	5.80	**4.25**
L_2	0.30	0.50	0.87	0.66	**0.58**	1.05	1.20	3.07	1.10	**1.60**	3.05	2.70	3.76	1.81	**2.83**	3.66	3.66	4.33	2.33	**3.50**	4.79	4.82	5.50	3.37	**4.62**
L_3	0.83	0.78	0.30	0.75	**0.66**	1.60	1.94	2.27	2.40	**2.05**	2.92	3.97	3.25	3.73	**3.47**	3.33	4.33	3.66	4.33	**3.91**	4.51	5.51	4.84	5.45	**5.08**
Mean	**0.44**	**0.54**	**0.68**	**0.58**		**1.30**	**1.47**	**2.23**	**1.58**		**2.53**	**2.66**	**3.45**	**3.15**		**3.11**	**3.33**	**3.88**	**3.77**		**4.22**	**4.47**	**5.04**	**4.87**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.08	0.10	0.17			0.46	0.53	0.93			0.57	0.66	1.15			0.44	0.51	0.88			0.44	0.51	0.88		

denotes the significant effect of root pruning and nitrogen level on white root regeneration at different growth stages from 30 to 150 days after planting.

At 30 days after planting, the maximum white root regeneration (18.66) was recorded in L_3 followed by L_2 i.e. (8.66) while the minimum white root regeneration (5.62) was observed under L_1 (control). Among the different nitrogen doses, the highest white root (14.66) was recorded in N_3 which was followed by N_4 i.e. (10.88) while the minimum white root (8.11) was recorded in N_1 (control). Furthermore, the interaction (L×N) was found to be significant. However, the highest white root (26.66) for interaction was reported under (L_3×N_3) whereas the lowest white root (4.33) was observed in (L_1×N_2).

At 60 days after planting, the highest white root regeneration (20.90) was observed in L_3 followed by L_2 i.e. (10.89) while the lowest white root regeneration (7.81) was recorded under L_1 (control). Among the different nitrogen doses, the highest white root (16.93) was recorded in N_3 which was followed by N_4 i.e. (13.07) while the minimum white root (10.32) was recorded in N_1 (control). Furthermore, the interaction (L×N) was found to be significant. However, the highest white root (29.06) for interaction was reported under (L_3×N_3) whereas the lowest white root (6.63) was observed in (L_1×N_2).

At 90 days after planting, the maximum value for white root regeneration (23.91) was obtained in L_3 which was followed by L_2 i.e. (14.50) and the minimum white root (12.45) was observed under L_1 (control). Among the different nitrogen doses, the maximum white root (20.55) was recorded in N_3 followed by N_4 i.e. (17.88) while the minimum white root (13.11) was recorded in N_1 (control). Moreover, the interaction (L×N) was found to be significant for all the treatments. However; the highest regeneration of white root (32.66) was

reported under ($L_3 \times N_3$) and while the lowest white root (10.33) was observed in ($L_1 \times N_2$).

At 120 days after planting, the highest white root regeneration (25.13) was observed in L_3 followed by L_2 i.e. (15.83) while the lowest white root (13.67) was observed under L_1 (control). For the different nitrogen doses, the maximum white root (21.80) was recorded in N_3 which was statistically at par with N_4 i.e. (19.21) while the minimum white root (14.33) was recorded in N_1 (control). The results further demonstrated the significant Interaction for all the treatments however; the maximum white root (33.96) was reported under ($L_3 \times N_3$) while the lowest white root (11.63) was observed in ($L_1 \times N_2$).

At 150 days after planting, the maximum white root regeneration (25.91) was obtained in L_3 which was followed by L_2 i.e. (16.50) whereas the minimum white root (14.45) was observed under L_1 (control). Among the nitrogen application, the maximum white root (22.55) was recorded in N_3 which was at par with N_4 i.e. (19.88) while the minimum white root (15.11) was recorded in N_1 (control). The interaction between root pruning and nitrogen application ($L \times N$) was found to be significant. However, the highest regeneration of white root (34.66) was reported under ($L_3 \times N_3$) while the lowest white root (12.33) was observed in ($L_1 \times N_2$).

4.2.2. Survival percent (%)

The data related to survival percent (%) was showed in Table 4.12 reveals that the survival percent was improved with the application of nitrogen and root pruning. However, the maximum survival percent (94.50%) was recorded in L_3 which was followed by L_2 i.e. (91.50%) while the lowest (84.75%) survival was recorded under L_1. For the different doses of nitrogen, the highest percent (94.66%) was observed in N_3 treatment which was at par with N_4 i.e. (92.00%)

Table 4.11 :- The effect of root pruning length and nitrogen application on white root regeneration in *Celtis australis* at various growth stages.

White root regeneration

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	4.66	4.333	8.00	5.50	**5.62**	6.86	6.63	10.10	7.66	**7.81**	10.66	10.33	14.33	14.50	**12.45**	11.80	11.63	15.43	15.83	**13.67**	12.66	12.33	16.33	16.50	**14.45**
L_2	8.50	8.50	9.33	8.33	**8.66**	10.70	10.66	11.63	10.56	**10.89**	14.50	14.50	14.66	14.33	**14.50**	15.80	15.76	16.00	15.76	**15.83**	16.50	16.50	16.66	16.33	**16.50**
L_3	11.16	18.00	26.66	18.83	**18.66**	13.40	20.13	29.06	21.0	**20.90**	14.16	24.00	32.66	24.83	**23.91**	15.40	25.13	33.96	26.03	**25.13**	16.16	26.00	34.66	26.83	**25.91**
Mean	**8.11**	**10.27**	**14.66**	**10.88**		**10.32**	**12.47**	**16.93**	**13.07**		**13.11**	**16.27**	**20.55**	**17.88**		**14.33**	**17.51**	**21.80**	**19.21**		**15.11**	**18.27**	**22.55**	**19.88**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	2.36	2.72	4.72			2.31	2.67	4.63			2.28	2.64	4.57			2.25	2.60	4.51			2.289	2.643	4.579		

Table 4.12 :- The effect of root pruning length and nitrogen application on survival% in *Celtis australis* at various growth stages.

	Survival %					
	150 DAP					
	N_1	N_2	N_3	N_4	Mean	
L_1	80.00	75.00	98.00	86.00	**84.75**	
L_2	90.00	94.00	88.00	94.00	**91.50**	
L_3	90.00	94.00	98.00	96.00	**94.50**	
Mean	**86.66**	**87.66**	**94.66**	**92.00**		
CD	L	N	L×N			
	1.70	1.96	3.40			

while the lowest percent of survival (86.66%) was recorded in N_1. The results further demonstrated the significant interaction for all the treatment, however, the maximum survival percent (98.00%) was noted under ($L_1 \times N_3$) and ($L_3 \times N_3$) at 150 days after planting.

4.2.3. Chlorophyll 'a' (mg g^{-1})

The perusal of data for chlorophyll 'a' presented in Table 4.13 revealed the significant effect of root pruning and nitrogen level on chlorophyll 'a' at 60 and 120 days after planting.

At 120 days after planting, the highest concentration of chlorophyll 'a' (2.48) was recorded under L_3 which was followed by L_2 (1.92 mg g^{-1}) while the minimum concentration (1.54 mg g^{-1}) was observed in L_1 and among the nitrogen doses used in the research, the concentration of chlorophyll 'a' was recorded maximum (3.41 mg g^{-1}) in N_3 which was significantly at par to N_4 i.e. (1.74 mg g^{-1}) while the minimum concentration (1.12 mg g^{-1}) was noted under N_1.The interaction effect between length of root pruning and nitrogen doses was found to be statistically significant and the highest concentration of chlorophyll 'a' (6.68 mg g^{-1}) was recorded in ($L_3 \times N_3$) while the lowest concentration (0.46 mg g^{-1}) was recorded in ($L_3 \times N_1$).

4.2.4. Chlorophyll 'b' (mg g^{-1})

The data for chlorophyll 'b' was depicted in Table 4.14 reveals the significant effect on chlorophyll 'b'. At 60 days after planting, the highest concentration of chlorophyll 'b' (2.09 mg g^{-1}) was reported significantly superior in L_3 which was at par to L_2 i.e. (1.85) while the lowest concentration (1.42 mg g^{-1}) was noted in L_1. Among the nitrogen doses used in the research, the concentration of chlorophyll 'b' (1.98 mg g^{-1}) was reported maximum in N_3

Table 4.13 :- The effect of root pruning length and nitrogen application on chlorophyll content of 'a' in *Celtis australis* at various growth stages.

Chlorophyll 'a'										
	60 DAP					**120 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.22	0.22	0.20	0.19	**0.20**	0.84	0.48	1.99	2.85	**1.54**
L_2	0.20	0.20	0.21	0.23	**0.21**	2.07	2.82	1.58	1.21	**1.92**
L_3	0.22	0.24	0.34	0.24	**0.26**	0.46	1.63	6.68	1.17	**2.48**
Mean	**0.21**	**0.22**	**0.25**	**0.22**		**1.12**	**1.64**	**3.41**	**1.74**	
CD	L	N	L×N			L	N	L×N		
	0.01	0.02	0.03			0.30	0.34	0.60		

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which was significantly at par with N_4 i.e. (1.84 mg g^{-1}) while the minimum concentration (1.66 mg g^{-1}) was noted under N_1. The interaction between both factors was found to be significant for concentration of chlorophyll 'b' however; the maximum value (2.48 mg g^{-1}) was recorded in ($L_3 \times N_3$) while the minimum concentration (1.22 mg g^{-1}) was recorded in ($L_1 \times N_2$).

At 120 days after planting, the maximum concentration of chlorophyll 'b' (13.84 mg g^{-1}) was recorded under L_3 which was followed by L_2 and L_1. While the minimum concentration of chlorophyll 'b' (9.55 mg g^{-1}) was noticed in L_2 which was significantly at par with L_1 (9.89 mg g^{-1}) and among the nitrogen doses, the maximum concentration of chlorophyll 'b' (12.62 mg g^{-1}) was recorded in N_3 which was significantly at par with N_4 i.e. (11.18 mg g^{-1}) and the minimum concentration of chlorophyll 'b' (10.16 mg g^{-1}) was noted under N_1. The interaction between length of root pruning and nitrogen doses for concentration of chlorophyll 'b' was found statistically significant and the highest concentration of chlorophyll 'b' (20.92 mg g^{-1}) was found in ($L_3 \times N_3$) while the lowest concentration of chlorophyll 'b' (7.50 mg g^{-1}) was recorded in ($L_2 \times N_3$).

4.2.5. Total Chlorophyll (mg g^{-1})

The data showed in Table 4.15 indicate the significant effect on total chlorophyll. At 60 days after planting, the root pruning had a significant effect on concentration of total chlorophyll whereas the maximum concentration (1.85 mg g^{-1}) was recorded under L_3 which was statistically superior to L_2 (1.64 mg g^{-1}) and L_1 (1.27 mg g^{-1}) while L_1 remains statistically minimum. Among the nitrogen doses, the maximum concentration of total chlorophyll (1.76 mg g^{-1}) was reported in N_3 which was at par with N_4 i.e. (1.64 mg g^{-1}) while the minimum concentration of total chlorophyll (1.48 mg g^{-1}) was found in N_2 and N1. The interaction between length of root pruning and nitrogen doses was found to be

Table 4.14 :- The effect of root pruning length and nitrogen application on chlorophyll content of 'b' in *Celtis australis* at various growth stages.

Chlorophyll 'b'										
	60 DAP					**120 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	1.43	1.22	1.65	1.41	**1.42**	9.39	9.56	9.44	11.18	**9.89**
L_2	1.71	2.10	1.83	1.76	**1.85**	10.17	9.98	7.50	10.58	**9.55**
L_3	1.86	1.68	2.48	2.36	**2.09**	10.92	11.74	20.92	11.78	**13.84**
Mean	**1.66**	**1.66**	**1.98**	**1.84**		**10.16**	**10.42**	**12.62**	**11.18**	
CD	L	N	L×N			L	N	L×N		
	0.18	0.21	0.36			1.47	1.70	2.95		

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statistically significant and the concentration of total chlorophyll (2.20 mg g^{-1}) was found maximum in ($L_3 \times N_3$) while the minimum concentration (1.09 mg g^{-1}) was recorded in ($L_1 \times N_2$).

At 120 days after planting, the highest concentration of total chlorophyll (12.19 mg g^{-1}) was found in L_3 which was statistically superior to L_2 (8.72 mg g^{-1}) and L_1 (8.47 mg g^{-1}) while the minimum was recorded in L_1. Among the nitrogen doses, the maximum concentration of total chlorophyll (11.11 mg g^{-1}) was reported in N_3 which was statistically superior to N_4, N_2 and N_1 while the minimum concentration (9.04 mg g^{-1}) was observed in N_1 which was statistically at par with N_2 (9.17 mg g^{-1}) and N_4 (9.86 mg g^{-1}). The interaction between length of root pruning and nitrogen doses was found to be statistically significant and the maximum concentration (18.43 mg g^{-1}) was reported in ($L_3 \times N_3$) while the minimum concentration (6.64 mg g^{-1}) was recorded in ($L_1 \times N_3$).

4.3. Nutritional parameters

The data on nutritional parameters viz. nitrogen concentration (%) & uptake (kg/ha), phosphorus concentration (%) & uptake (kg/ha) and potassium concentration (%) & uptake (kg/ha) are presented under following heads;

4.3.1. Nitrogen concentration (%)

The effect of root pruning length and nitrogen doses on concentration of nitrogen in *Celtis australis* at various growth stages is presented in Table 4.16. The results reveal that root pruning had a significant effect on the concentration of nitrogen. The data further revealed that highest concentration of nitrogen was recorded with L_3 at all the growth stages (30, 60, 90, 120 and 150 Days after planting) whereas planting of *Celtis australis* without pruning showed the lowest concentration of nitrogen during every growth stage.

Table 4.15 :- The effect of root pruning length and nitrogen application on total chlorophyll content in *Celtis australis* at various growth stages

Total Chlorophyll

	60 DAP					**120 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	1.27	1.09	1.46	1.26	**1.27**	9.21	8.75	6.64	9.31	**8.47**
L_2	1.52	1.87	1.63	1.57	**1.64**	8.30	8.40	8.28	9.91	**8.72**
L_3	1.65	1.49	2.20	2.09	**1.85**	9.63	10.36	18.43	10.36	**12.19**
Mean	**1.48**	**1.48**	**1.76**	**1.64**		**9.04**	**9.17**	**11.11**	**9.86**	
CD	L	N	L×N			L	N	L×N		
	0.12	0.14	0.24			0.88	1.02	1.77		

At 30 days after planting, the highest concentration of nitrogen (0.26%) was recorded under L_3 which was significantly higher than L_2 (0.22%) and L_1 (0.12%). Among the different nitrogen doses used in the study, the highest concentration of nitrogen was noted for N_3 i.e. (0.24%) which was statistically at par to N_4 (150Kg/ha) i.e. 0.21% while the least concentration of nitrogen (0.16%) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was also found to be statistically significant. The maximum concentration of nitrogen was found with interaction of root pruning length of 12cm (L_3) along with application of N@150 Kg/ ha (N_4) i.e. $L_3 \times N_4$ (0.36%) whereas the minimum concentration was noted under ($L_1 \times N_1$) i.e. (0.03%) in plants.

At 60 days after planting, the highest concentration of nitrogen (0.33%) recorded was under L_2 and L_3 (0.34%) which were statistically at par with each other while the minimum concentration (0.28%) was recorded in L_1. Among the nitrogen doses used in the study, the highest concentration of nitrogen (0.46%) was noted for N_3 (100 Kg/ha) which was statistically at par to N_4 (150 Kg/ha) i.e. 0.37% whereas the least concentration of nitrogen was recorded in N_1 (control) i.e. 0.12%. The interaction between length of root pruning and nitrogen doses was also found to be statistically significant with maximum concentration of nitrogen found with the root pruning length of 12cm (L_3) along with application of N@100 Kg/ ha (N_4) i.e. ($L_3 \times N_3$) (0.58%) whereas the minimum concentration of nitrogen (0.02%) was recorded in ($L_1 \times N_1$).

At 90 days after planting, the higher concentration of nitrogen (0.94%) was recorded under L_3 which was significantly higher than L_2 (0.34%) and L_1 (0.31%). Among the different nitrogen doses used in the study, the highest concentration of nitrogen (0.81%) was recorded for N_3 (100 Kg/ha) which was statistically at par to N_4 (150Kg/ha) i.e. 0.54% while the least concentration of

nitrogen (0.32%) was recorded in N_1 (control). The interaction effect of length of root pruning and nitrogen doses was also found to be statistically significant with the maximum concentration of nitrogen (1.70%) found with (L_3) along with (N_4) i.e. ($L_3 \times N_3$) (1.70%) while the minimum concentration of nitrogen (0.16%) was recorded in i.e.($L_1 \times N_2$) and ($L_1 \times N_4$).

At 120 days after planting, the highest concentration of nitrogen (0.44%) was recorded under L_3 which was significantly higher than L_2 (0.34%) and L_1 (0.31%). Among the different nitrogen doses, the highest concentration of nitrogen (0.43%) was noted for N_3 (100 Kg/ha) which was statistically at par to N_4 (150 Kg/ha) i.e. 0.39% whereas the least concentration of nitrogen (0.31%) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was also found to be statistically significant. The maximum concentration of nitrogen (0.58%) was found with the root pruning length of 12cm (L_3) along with application of N@150 Kg/ ha (N_4) i.e. ($L_3 \times N_4$) whereas the minimum concentration of nitrogen (0.17%) was noted under ($L_2 \times N_2$).

At 150 days after planting, the highest concentration of nitrogen (0.99%) was recorded under L_3 followed by L_2 (0.27%) and L_1 (0.15%) whereas among the nitrogen doses, the highest concentration of nitrogen (0.54%) was noted for N_3 (100 Kg/ha) which was statistically at par to N_4 (150 Kg/ha) while the least concentration of nitrogen (0.39%) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant with maximum concentration of nitrogen (1.29%) found with the root pruning length of 12cm (L_3) along with application of N@150 Kg/ ha (N_4) i.e. ($L_3 \times N_4$) (1.29%) while the minimum concentration of nitrogen (0.01%) was noted under ($L_1 \times N_2$), ($L_1 \times N_4$) and ($L_2 \times N_1$).

Table 4.16 :- The effect of root pruning length and nitrogen application on concentration of nitrogen in *Celtis australis* at various growth stages.

Nitrogen concentration %

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.03	0.25	0.22	0.01	**0.12**	0.02	0.16	0.50	0.44	**0.28**	0.36	0.16	0.56	0.16	**0.31**	0.30	0.45	0.25	0.28	**0.32**	0.30	0.01	0.28	0.01	**0.15**
L_2	0.25	0.03	0.34	0.28	**0.22**	0.30	0.50	0.30	0.22	**0.33**	0.30	0.72	0.16	0.17	**0.34**	0.22	0.17	0.73	0.31	**0.35**	0.01	0.48	0.31	0.30	**0.27**
L_3	0.22	0.31	0.17	0.36	**0.26**	0.03	0.31	0.58	0.44	**0.34**	0.30	0.47	1.70	1.28	**0.94**	0.42	0.44	0.31	0.58	**0.44**	0.87	0.78	1.04	1.29	**0.99**
Mean	**0.16**	**0.19**	**0.24**	**0.21**		**0.12**	**0.32**	**0.46**	**0.37**		**0.32**	**0.45**	**0.81**	**0.54**		**0.31**	**0.35**	**0.43**	**0.39**		**0.39**	**0.42**	**0.54**	**0.53**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.04	0.05	0.08			0.02	0.03	0.05			0.28	0.32	0.56			0.01	0.02	0.03			0.01	0.02	0.03		

4.3.2. Nitrogen uptake (Kg/ha)

The data pertinent to nitrogen uptake presented in Table 4.17 showed that the root pruning had a significant effect on nitrogen uptake where the root pruning length of 12 cm (L_3) had highest uptake of nitrogen at all growth stages whereas the planting of *Celtis australis* without pruning showed lowest uptake of nitrogen during every growth stage.

At 30 days after planting, the maximum uptake of nitrogen (13.78 Kg/ha) was recorded under L_3 which was followed by L_2 (9.49 Kg/ha) and significantly higher than L_1 (7.19 Kg/ha). Among the different nitrogen doses, the highest uptake of nitrogen (14.62 Kg/ha) was noted for N_3 (@100 Kg/ha) followed by N_4 (150 Kg/ha) i.e. 10.71 Kg/ha whereas the lowest uptake of N_1 (control) i.e. 6.82 Kg/ha. The interaction between length of root pruning and nitrogen doses was also found to be statistically significant. The highest uptake of nitrogen (28.25 Kg/ha) was found with the root pruning length of 12cm (L_3) along with application of N@100 Kg/ha (N_3) i.e. ($L_3 \times N_3$) while the minimum uptake of nitrogen (0.14 Kg/ha) was found in ($L_1 \times N_3$).

At 60 days after planting, the highest uptake of nitrogen (19.67 Kg/ha) was recorded under L_3 which was followed by L_2 (15.70 Kg/ha) and significantly higher than L_1 (11.91 Kg/ha). Among the different nitrogen doses, the highest uptake of nitrogen (24.92 Kg/ha) was noted for N_3 (100 Kg/ha) followed by N_4 (150 Kg/ha) i.e. 17.75 Kg/ha while the minimum uptake of nitrogen was recorded in N_1 (control) i.e. 6.35 Kg/ha. The interaction between length of root pruning and nitrogen doses was also found to be statistically significant. The highest uptake of nitrogen 36.35 Kg/ha was found with the root pruning length of 12cm (L_3) along with application of N@100Kg/ha (N_3) i.e. ($L_3 \times N_3$) while the minimum uptake was found under ($L_1 \times N_1$) i.e. (1.43 Kg/ha).

At 90 days after planting, the maximum uptake of nitrogen (57.54 Kg/ha) was recorded under L_3 which was followed by L_2 i.e. (17.30 Kg/ha) while the minimum concentration of nitrogen was recorded in L_1 (16.47 Kg/ha). Among the nitrogen doses, the highest uptake of nitrogen was noted in N_3 i.e. 48.30 Kg/ha which was followed by N_4 i.e. 37.53 Kg/ha while the minimum uptake of nitrogen was recorded in N_1 i.e. 16.77 Kg/ha. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stages. The highest uptake of nitrogen 105.75 Kg/ha was recorded in $L_3 \times N_3$ while the minimum uptake was recorded under ($L_1 \times N_4$) i.e. (2.26 Kg/ha).

At 120 days after planting, the highest uptake of nitrogen (23.46 Kg/ha) was recorded under L_3 which was followed by L_2 i.e. (14.97 Kg/ha) while the minimum uptake of nitrogen was recorded under L_1 (13.73 Kg/ha). Among the different nitrogen doses, the highest uptake of nitrogen was noted for N_3 i.e. 22.31 Kg/ha which was followed by N_4 i.e. 17.23 Kg/ha while the minimum uptake of nitrogen (13.86 Kg/ha) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stages. The highest uptake of nitrogen (46.03 Kg/ha) was found in ($L_3 \times N_3$) while the minimum uptake was recorded under ($L_2 \times N_3$) i.e. (3.79 Kg/ha).

At 150 days after planting, the maximum uptake of nitrogen (55.58 Kg/ha) was recorded under L_3 which was followed by L_2 (12.79 Kg/ha) while the minimum uptake was recorded in L_1 (8.72 Kg/ha). Among the nitrogen doses, the highest uptake of nitrogen was noted for N_3 i.e. (39.44 Kg/ha) which was followed by N_4 i.e. (29.71 Kg/ha) while the minimum uptake of nitrogen (13.73 Kg/ha) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stages. The highest uptake of nitrogen was found in ($L_3 \times N_3$) i.e. (101.21 Kg/ha) while the minimum uptake was recorded under ($L_2 \times N_2$) i.e. (0.70 Kg/ha).

Table 4.17 :- The effect of root pruning length and nitrogen application on uptake of nitrogen in *Celtis australis* at various growth stages.

Nitrogen uptake (Kg/ha)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	13.23	1.61	0.14	13.80	**7.19**	1.43	8.82	31.36	6.04	**11.91**	19.47	8.82	35.33	2.26	**16.47**	9.53	11.48	17.13	16.80	**13.73**	0.71	16.43	0.18	17.56	**8.72**
L_2	1.65	13.05	15.47	7.82	**9.49**	16.01	27.57	7.06	12.16	**15.70**	16.01	39.97	3.84	9.39	**17.30**	23.99	16.43	3.79	15.68	**14.97**	26.40	0.70	16.95	7.13	**12.79**
L_3	5.60	10.77	28.25	10.53	**13.78**	1.63	5.66	36.35	35.05	**19.67**	14.85	8.61	105.75	100.95	**57.54**	8.07	20.56	46.03	19.21	**23.46**	14.09	42.60	101.21	64.44	**55.58**
Mean	**6.82**	**8.47**	**14.62**	**10.71**		**6.35**	**14.01**	**24.92**	**17.75**		**16.77**	**19.13**	**48.30**	**37.53**		**13.86**	**16.15**	**22.31**	**17.23**		**13.73**	**19.91**	**39.44**	**29.71**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.01	0.01	0.02			0.01	0.01	0.02			0.01	0.01	0.02			0.01	0.01	0.03			0.01	0.01	0.02		

4.3.3. Phosphorus concentration (%)

The perusal of data for phosphorus concentration presented in Table 4.18 indicates the root pruning and nitrogen application had maximum concentration of phosphorus at all the growth stages (30, 60, 90, 120 and 150 Days after planting).

At 30 days after planting, the maximum concentration (0.36%) was recorded under L_3 which was statistically at par to L_2 i.e. (0.32%) and significantly higher to L_1 i.e. (0.24%). Among the different nitrogen doses, the highly significant value was observed under N_3 treatment which obtained a concentration of phosphorus i.e. (0.37%) which was followed by N_4 i.e. (0.30%) while the minimum concentration (0.26%) was found in N_1. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum concentration of phosphorous (0.48%) was observed in ($L_3 \times N_3$) while the minimum concentration was found under ($L_1 \times N_2$) i.e. (0.12%).

At 60 days after planting, the highest concentration (0.35%) recorded under L_3 which was followed by L_2 i.e. (0.30%) and significantly higher to L_1 i.e. (0.28%) and among the different nitrogen doses, the highly significant value (0.34%) was observed under N_3 treatment which was followed by N_4 i.e. (0.31%) while the minimum concentration (0.28%) was found in N_1. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum concentration of phosphorous (0.39%) was observed in ($L_3 \times N_1$) while the minimum concentration (0.21%) was found under ($L_1 \times N_1$)

At 90 days after planting, the maximum concentration (0.36%) was recorded in L_3 which was followed by L_2 i.e. (0.33%) and significantly higher to L_1 (0.28%). Among the different nitrogen doses, the maximum value (0.38%) was

observed under N_3 treatment which was followed by N_4 i.e. (0.33%) while the minimum concentration (0.26%) was recorded in N_1. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum concentration of phosphorous (0.44%) was recorded in ($L_3 \times N_3$) while the minimum concentration (0.23%) was found under ($L_1 \times N_1$) and ($L_1 \times N_2$).

At 120 days after planting, the highest concentration (0.38%) recorded under L_3 which was followed by L_2 i.e. (0.37%) and significantly higher to L_1 i.e. (0.28%) and among the different nitrogen doses, the highly significant value (0.44%) was observed under N_3 which was followed by N_4 i.e. (0.33%) while the minimum concentration (0.30%) was recorded in N_1. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum concentration of phosphorous (0.74%) was observed in ($L_3 \times N_3$) while the minimum concentration (0.14%) was found under ($L_1 \times N_3$).

At 150 days after planting, the maximum concentration (0.29%) recorded under L_3 was followed by L_2 i.e. (0.28%) and significantly higher to L_1 i.e. (0.26%). Among the different nitrogen doses, the highly significant value (0.31%) was observed under N_3 which was followed by N_4 i.e. (0.29%) while the minimum concentration (0.24%) was recorded in N_1. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum concentration of phosphorous (0.39%) was observed in ($L_3 \times N_3$) while the minimum concentration (0.22%) was recorded under ($L_1 \times N_1$).

4.3.4. Phosphorus uptake (kg/ha)

The data for phosphorus uptake depicted in Table 4.19 reveals that root pruning and nitrogen doses had a significant effect on phosphorus uptake. At 30

Table 4.18 :- The effect of root pruning length and nitrogen application on concentration of phosphorus in *Celtis australis* at various growth stages.

Phosphorus concentration (%)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.27	0.12	0.30	0.27	**0.24**	0.21	0.30	0.30	0.33	**0.28**	0.23	0.23	0.34	0.31	**0.28**	0.25	0.52	0.14	0.23	**0.28**	0.22	0.28	0.24	0.32	**0.26**
L_2	0.24	0.44	0.33	0.29	**0.32**	0.26	0.30	0.36	0.28	**0.30**	0.29	0.29	0.38	0.38	**0.33**	0.44	0.22	0.44	0.40	**0.37**	0.28	0.28	0.32	0.26	**0.28**
L_3	0.29	0.33	0.48	0.35	**0.36**	0.39	0.32	0.37	0.32	**0.35**	0.27	0.42	0.44	0.31	**0.36**	0.22	0.21	0.74	0.35	**0.38**	0.23	0.26	0.39	0.30	**0.29**
Mean	**0.26**	**0.29**	**0.37**	**0.30**		**0.28**	**0.30**	**0.34**	**0.31**		**0.26**	**0.31**	**0.38**	**0.33**		**0.30**	**0.32**	**0.44**	**0.33**		**0.24**	**0.27**	**0.31**	**0.29**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.01	0.02	0.03			0.02	0.02	0.04			0.02	0.02	0.04			0.03	0.04	0.07			0.01	0.02	0.03		

days after planting, the maximum uptake of phosphorus (17.07 Kg/ha) was observed in L_3 treatment which was statistically at par to L_2 treatment i.e. (15.96 Kg/ha) and significantly higher to L_1 treatment i.e. (11.91 Kg/ha). Among the different nitrogen doses, the maximum uptake of phosphorus (16.46 Kg/ha) was observed in N_3 treatment which was statistically at par to N_4 treatment i.e. (15.67 Kg/ha) while the minimum uptake (13.57 Kg/ha) was found in N_1 treatment. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of phosphorous (27.60 Kg/ha) was observed in ($L_2 \times N_2$) while the minimum uptake of phosphorous (3.24 Kg/ha) was observed in ($L_2 \times N_1$).

At 60 days after planting, the maximum uptake of phosphorus (18.60 kg/ha) was observed in L_3 treatment which was followed by L_2 i.e. (13.14 Kg/ha) and statistically at par to L_1 treatment (13.11 Kg/ha). Among the different nitrogen doses, the maximum uptake of phosphorus (16.91 Kg/ha) was observed in N_3 treatment which was statistically at par to N_4 treatment (15.32 kg/ha) while the minimum uptake was found in N_1 treatment (12.91 Kg/ha). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of phosphorous (29.20 Kg/ha) was observed in ($L_3 \times N_3$) while the minimum uptake of phosphorous (4.87 Kg/ha) was observed in ($L_1 \times N_3$).

At 90 days after planting, the highest uptake of phosphorus (17.48 Kg/ha) was observed in L_3 treatment which was followed by L_2 treatment i.e. (16.52 Kg/ha) and statistically at par to L_1 treatment i.e. (13.55 Kg/ha) and among the nitrogen doses, the maximum uptake of phosphorus (17.90 Kg/ha) was observed in N_3 treatment which was statistically at par to N_4 treatment (16.81 Kg/ha) while the minimum uptake was found in N_1 treatment (12.74 Kg/ha). The interaction between length of root pruning and nitrogen doses was found to be statistically

significant at each growth stage. The maximum uptake of phosphorous (26.34 Kg/ha) was observed in ($L_3 \times N_2$) while the minimum uptake of phosphorous (3.70 Kg/ha) was observed in ($L_3 \times N_1$).

At 120 days after planting, the maximum uptake of phosphorus (21.29 Kg/ha) was observed in L_3 treatment which was followed by L_2 treatment i.e. (17.81 Kg/ha) and statistically at par to L_1 treatment i.e. (16.04 Kg/ha). Among the nitrogen application, the maximum uptake of phosphorus (22.79 Kg/ha) was observed in N_3 treatment which was statistically at par to N_4 treatment (20.35 Kg/ha) while the minimum uptake (14.52 Kg/ha) was found in N_1 treatment. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of phosphorous (38.98 Kg/ha) was observed in ($L_2 \times N_3$) while the minimum uptake of phosphorous (4.09 Kg/ha) was observed in ($L_3 \times N_1$).

At 150 days after planting, the highest uptake of phosphorus (16.51 Kg/ha) was observed in L_3 treatment which was followed by L_2 treatment i.e. (12.64 Kg/ha) and statistically at par to L_1 treatment (12.62 Kg/ha). Among the different nitrogen application, the maximum uptake of phosphorus (16.41 Kg/ha) was observed in N_3 treatment which was statistically at par to N_4 treatment i.e. (14.46 Kg/ha) while the minimum uptake (10.60 Kg/ha) was found in N_1 treatment. The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of phosphorous (30.60 Kg/ha) was observed in ($L_3 \times N_3$) while the minimum uptake of phosphorous (4.15 Kg/ha) was recorded with in ($L_3 \times N_1$).

4.3.5. Potassium concentration (%)

A close perusal of potassium concentration is presented in Table 4.20 which indicates that root pruning and nitrogen level had significant effect on

Table 4.19 :- The effect of root pruning length and nitrogen application on uptake of phosphorus in *Celtis australis* at various growth stages.

Phosphorus uptake (Kg/ha)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	21.45	7.44	5.54	13.22	**11.91**	14.82	13.93	4.87	18.82	**13.11**	18.31	14.46	15.18	6.26	**13.55**	27.94	14.63	7.86	13.75	**16.04**	12.65	7.82	14.37	15.66	**12.62**
L_2	3.24	27.60	17.46	15.54	**15.96**	18.15	10.96	16.58	6.90	**13.14**	16.21	7.08	21.92	20.90	**16.52**	11.55	8.21	38.98	12.53	**17.81**	15.00	16.31	4.28	15.00	**12.64**
L_3	16.03	7.59	26.40	18.27	**17.07**	5.78	19.09	29.2	20.24	**18.60**	3.70	26.34	16.61	23.28	**17.48**	4.09	24.78	21.54	34.78	**21.29**	4.15	18.59	30.60	12.73	**16.51**
Mean	**13.57**	**14.21**	**16.46**	**15.67**		**12.91**	**14.66**	**16.91**	**15.32**		**12.74**	**15.96**	**17.90**	**16.81**		**14.52**	**15.87**	**22.79**	**20.35**		**10.60**	**14.24**	**16.41**	**14.46**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	1.79	2.06	3.58			1.55	1.79	3.11			1.26	1.45	2.52			1.20	1.39	2.41			1.75	2.02	3.50		

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potassium concentration. At 30 days after planting, the maximum concentration of potassium (1.31%) was recorded in L_3 which was significantly higher to L_1 and L_2 (1.00%) and among the different nitrogen application, the highly significant value (1.41%) was observed under N_3 treatment which was statistically at par to N_4 treatment i.e. (1.25%) and significant to N_1 treatment (control) i.e. (0.755%). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (1.75%) was observed in ($L_1 \times N_4$) while the minimum uptake of phosphorous (0.49%) was recorded in ($L_1 \times N_3$).

At 60 days after planting, the maximum concentration of potassium (1.75%) was recorded in L_3 which was significantly higher to L_1 and L_2 i.e. (1.00%) and among the nitrogen application, the highly significant value (1.66%) was observed under N_3 treatment which was statistically at par to N_4 treatment i.e. (1.25%) and significant to N_1 treatment (control) i.e. (0.755%). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (2.25%) was observed in ($L_3 \times N_3$) while the minimum uptake of phosphorous (0.49%) was observed in ($L_1 \times N_3$).

At 90 days after planting, the highest concentration of potassium (1.87%) was recorded in L_3 which was followed by L_2 i.e. (1.54%) and significantly higher to L_1 i.e. (1.06%). Among the nitrogen application, the highly significant value (1.75%) was observed under N_3 treatment which was statistically at par to N_4 treatment i.e. (1.46%) and significant to N_1 treatment (control) i.e. (1.33%). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (2.50%) was recorded in ($L_2 \times N_3$) while the minimum uptake of phosphorous (0.99%) was observed under ($L_1 \times N_1$), ($L_1 \times N_2$) and ($L_1 \times N_4$).

At 120 days after planting, the maximum concentration of potassium (0.68%) was recorded in L_3 which was followed by L_2 i.e. (0.62%) and significantly higher to L_1 i.e. (0.56%) and among the nitrogen application, the highly significant value (0.99%) was observed under N_3 treatment which was followed by N_4 treatment i.e. (0.49%) and statistically at par with N_2 and N_1 treatment (control) i.e. (0.49%). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (1.50%) was observed in ($L_2 \times N_3$) while the minimum uptake of phosphorous was observed (0.25%) under ($L_2 \times N_1$) and ($L_2 \times N_2$).

At 150 days after planting, the highest concentration of potassium (1.25%) was recorded in L_3 which was followed by L_2 i.e. (0.68%) and significantly higher to L_1 i.e. (0.62%). Among the nitrogen application the highly significant value (1.33%) was observed under N_3 treatment which was followed by N_4 treatment i.e. (0.83%) while the minimum concentration (0.58%) was found under N_1 treatment (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (1.50%) was observed in ($L_2 \times N_3$) and ($L_3 \times N_4$) while the minimum uptake of potassium (0.24%) was observed in ($L_2 \times N_2$).

4.3.6. Potassium uptake (kg/ha)

The data presented in Table 4.21 indicated that potassium uptake at all growth stages significantly increased due to various fertility treatments over control at 30, 60, 90, 120 and 150 days after planting. At 30 days after planting, the maximum uptake of potassium (75.03 Kg/ha) was found under L_3 treatment which was followed by L_2 i.e. (49.33 Kg/ha) and significantly higher to L_1 (control) i.e. (47.88 Kg/ha). Among the different nitrogen doses, the maximum

Table 4.20 :- The effect of root pruning length and nitrogen application on concentration of potassium in *Celtis australis* at various growth stages.

Potassium concentration (%)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	0.75	1.00	0.49	1.75	**1.00**	0.75	1.25	1.50	0.50	**1.00**	0.99	0.99	1.25	0.99	**1.06**	0.49	0.49	0.75	0.49	**0.56**	0.25	0.50	1.25	0.50	**0.62**
L_2	0.50	1.25	1.50	0.75	**1.00**	0.75	0.99	1.25	2.00	**1.24**	1.25	1.03	2.50	1.40	**1.54**	0.25	0.25	1.50	0.50	**0.62**	0.50	0.24	1.50	0.50	**0.68**
L_3	1.00	0.75	2.25	1.25	**1.31**	1.50	1.50	2.25	1.75	**1.75**	1.75	2.25	1.50	2.00	**1.87**	0.74	0.74	0.74	0.50	**0.68**	1.00	1.25	1.25	1.50	**1.25**
Mean	**0.75**	**1.00**	**1.41**	**1.25**		**1.00**	**1.24**	**1.66**	**1.41**		**1.33**	**1.42**	**1.75**	**1.46**		**0.49**	**0.49**	**0.99**	**0.49**		**0.58**	**0.66**	**1.33**	**0.83**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.01	0.01	0.02			0.18	0.21	0.37			0.03	0.03	0.06			0.02	0.02	0.04			0.23	0.26	0.46		

uptake of potassium (77.99 Kg/ha) was noted under N_3 treatment while the lowest uptake of potassium (38.35 Kg/ha) was observed in N_1 (control) which was statistically at par to N_2 treatment i.e. (45.01 Kg/ha). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (139.41 Kg/ha) was observed in ($L_3 \times N_3$) while the minimum uptake of phosphorous (0.50 Kg/ha) was observed under ($L_1 \times N_3$).

At 60 days after planting, the maximum uptake of potassium (85.13 Kg/ha) was recorded under L_3 treatment which was followed by L_2 i.e. (52.18 Kg/ha) and significantly higher to L_1 (control) i.e. (42.00 Kg/ha). Among the different nitrogen doses, the maximum uptake of potassium (63.25 Kg/ha) was noted in N_3 treatment which was statistically at par to N_4 i.e. (62.92 Kg/ha) while the lowest uptake of potassium (50.98 Kg/ha) was observed in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (118.02 Kg/ha) was observed in ($L_3 \times N_3$) while the minimum uptake of phosphorous (16.91 Kg/ha) was observed under ($L_1 \times N_3$).

At 90 days after planting, the maximum uptake of potassium (99.62 Kg/ha) was found under L_3 treatment which was followed by L_2 i.e. (48.88 Kg/ha) and significantly higher to L_1 (control) i.e. (23.09 Kg/ha). Among the different nitrogen doses, the maximum uptake of potassium (73.90 Kg/ha) was reported in N_3 treatment which was statistically at par to N_4 i.e. (58.88 Kg/ha) while the lowest uptake of potassium (39.83 Kg/ha) was observed in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (137.31 Kg/ha) was observed in ($L_3 \times N_2$) while the minimum uptake of phosphorous (13.08 Kg/ha) was observed under ($L_1 \times N_4$).

At 120 days after planting, the maximum uptake of potassium (33.88 Kg/ha) was found under L_3 treatment which was followed by L_2 i.e. (31.40 Kg/ha) and significantly higher to L_1 (control) i.e. (26.09 Kg/ha). Among the different doses of nitrogen, the maximum uptake of potassium (51.68 Kg/ha) was noted under N_3 treatment which was statistically at par to N_4 i.e. (27.72 Kg/ha) while the lowest uptake of potassium (17.91 Kg/ha) was recorded in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium was observed ($L_2 \times N_3$) (78.30 Kg/ha) while the minimum uptake of phosphorous (5.75 Kg/ha) was observed in ($L_2 \times N_4$).

At 150 days after planting, the maximum uptake of potassium (68.26 Kg/ha) was found under L_3 treatment which was followed by L_2 i.e. (31.34 Kg/ha) and significantly higher to L_1 (control) i.e. (25.72 Kg/ha). Among the different nitrogen doses, the maximum uptake of potassium (63.45 Kg/ha) was noted under N_3 treatment which was statistically at par to N_4 i.e. (50.31 Kg/ha) while the minimum uptake of potassium (19.65 Kg/ha) was observed in N_1 (control). The interaction between length of root pruning and nitrogen doses was found to be statistically significant at each growth stage. The maximum uptake of potassium (116.35 Kg/ha) was observed in ($L_3 \times N_4$) while the minimum uptake of phosphorous (6.77 Kg/ha) was observed under ($L_2 \times N_4$).

Table 4.21:- The effect of root pruning length and nitrogen application on uptake of potassium in *Celtis australis* at various growth stages.

Potassium uptake (Kg/ha)

	30 DAP					**60 DAP**					**90 DAP**					**120 DAP**					**150 DAP**				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
L_1	39.15	55.18	0.50	96.71	**47.88**	40.36	31.36	16.91	79.38	**42.00**	26.25	17.75	35.28	13.08	**23.09**	26.32	6.71	40.19	31.15	**26.09**	27.68	12.88	34.52	27.81	**25.72**
L_2	26.79	66.33	94.08	10.15	**49.33**	39.15	46.03	54.82	68.75	**52.18**	66.15	13.49	62.51	53.40	**48.88**	13.93	27.63	78.30	5.75	**31.40**	13.23	26.97	78.40	6.77	**31.34**
L_3	49.12	13.54	139.41	98.08	**75.03**	73.44	108.43	118.02	40.63	**85.13**	27.09	137.31	123.92	110.16	**99.62**	13.48	39.23	36.56	46.26	**33.88**	18.06	61.20	77.45	116.35	**68.26**
Mean	**38.35**	**45.01**	**77.99**	**68.31**		**50.98**	**61.94**	**63.25**	**62.92**		**39.83**	**56.18**	**73.90**	**58.88**		**17.91**	**24.52**	**51.68**	**27.72**		**19.65**	**33.68**	**63.45**	**50.31**	
CD	L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N			L	N	L×N		
	0.04	0.04	0.08			0.61	0.70	1.22			0.01	0.01	0.02			0.01	0.01	0.02			0.37	0.43	0.75		

CHAPTER 5 DISCUSSION

The present investigation entitled **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"** was carried out during July to December 2019 in experiment fields of forest nursery block of College of Forestry, Ranichauri, Tehri Garhwal. This chapter has been devoted to discuss the result of the current study based on logical arguments and scientific evidence available in the literature.

5.1. Growth parameter of *Celtis australis*

5.1.1. Shoot length-

Root pruning has revealed significant effect on shoot length of seedlings. Shoot length in both (12 and 6 cm root pruning) treatments was significantly higher to control at 30 to 150 DAP. The increase in shoot length by root pruning might be due to the increase in number of root branching which might have produced high growth-promoting substances and transferred to the shoot portion. James and Hutto (1972) have also observed an increase in growth of perennial rye grass 24 days after root pruning. However, most literature reviewed showed decrease in shoot length due to root pruning (Andersen *et al*., 2002; Vasishth *et al*., 2007 and Bensona *et al*., 2019) and it could be suggested that the initial growth of seedlings increased and required to analyze seedlings for longer time to reveal proper effect of root pruning on seedling growth. Furthermore, the growth of plant is also dependent on the climatic and edaphic conditions of the site and physiological characteristics of the plant (Geisler and Ferree, 1984).

The nitrogen application also had significant effect on shoot length, which increased with the application of nitrogen upto 100kg N/ha (N_3) whereas the

minimum was recorded in control condition (N_1) during all stages of growth viz. 30, 60, 90, 120 and 150 DAP. This might due to the increase in cytokinin production which subsequently improves cell growth resulting in higher shoot length. Similar findings were observed by Lawlor (2002), Saini *et al*. (2002), Bloom *et al*. (2006), Sung-Joon *et al.* (2013) and Pramanik and Bera, (2013). However, dry weight and diameter growth was reduced by severe root pruning (Brown and Van den Driessche, 2005). Rao (1985) and Mishra (1987) in *Celtis australis* noticed that nitrogen doses at the rate of 80kg/ha had a positive response in relation to shoot growth. It's quite evident that the doses of nitrogen for a species depends upon the primary fertility status of soil, therefore, nitrogen up to 80kg/ha could have been found sufficient to meet the requirement of nitrogen in the seedlings. The results of present experiment are similar with the findings of Van Dorsser and Rook, 1972. Donald and Simpson (1985) observed significant responses of root pruned seedlings towards the fertilizer doses which was also reported by Sanjeev (1993), Vasishth *et al*. (2007) and Liu *et al.* (2010).

5.1.2. Root length

The root pruned seedlings had significant effect on root length. The maximum root length was observed in 12 cm root pruned seedlings from the collar region (L_3) at 30 to 150 DAP. The increase in root growth might be due to the availability of water in the soil which increases new root hairs growth, causing absorption of water and nutrients more effectively. This might also be due to accumulation of auxins on root tips, which increases the growth of new lateral roots and also helps to increase the length of root. Farmer and Pezeshki (2004) reported rapid new root growth in root pruned seedlings to overcome an imbalance in the root to shoot ratio in order to provide adequate water and nutrient absorption to support future plant growth and development. The similar results were found by Castle (1983), Pourmajidian *et al*. (2009, 2010) and Sung-joon *et al*. (2013).

The nitrogen application also had a significant impact on root length, where the maximum root length was observed in N_3 treatment (100kg N/ha) while the minimum root length was recorded under control condition (N_1). This might be due to the nitrogen fertilizer which affects water use efficiency by influencing root growth and enhances nutrient and water acquisition from the soil which helps to increase the root length. The results are in close confirmity with the Costa *et al.* (2002), Tian *et al.* (2005), Yang *et al.* (2012) and Kwon *et al.* (2019).

5.1.3. Collar diameter

Root pruning had significant effect on collar diameter of seedlings, reporting the maximum collar diameter with 12 cm pruning from the collar region (L_3) and the minimum in control (L_1) at 30 to 150 DAP. The reason may be that, the reserve carbohydrates may have been used for the cambial growth and is also influenced by the photosynthesis process. The similar results are found with the findings of Vasishth *et al.* (2007), Pourmajidian *et al.* (2009), Kasprzyk and Jastrzębowski (2016), Kerketta *et al.* (2017) and Kowalska and Kasprzyk (2018).

The application of nitrogen also had a significant effect on collar diameter. The average values of collar diameter increased with increasing nitrogen level upto 100kg N/ha while the minimum collar diameter was recorded under control condition (N_1). This might also be due to the increase in cytokinin production, which subsequently affects cell wall elasticity, number of meristematic cells and cell growth and increases the root collar diameter. The similar findings were obtained from the findings of Costa *et al.* (2002), Lawlor *et al.* (2002), Bloom, (2006), Huda *et al.* (2007), Cuesta *et al.* (2010), Sun *et al.* (2010) and Andivia *et al.* (2011).

5.1.4. Number of leaves

The root pruning had a significant effect on number of leaves at 30 to 150 DAP. The maximum numbers of leaves were produced in the seedlings with their roots pruned at 12 cm from the collar region (L_3) while the minimum number of leaves was recorded under control conditions (L_1). This may be due to the presence of auxin hormones in plants which helps to develop the new leaves and also depends on the process of photosynthesis. The similar findings were noted by Pourmajidian *et al*. (2009 and 2010) and Sung-Joon *et al*. (2013).

The different doses of nitrogen also had a significant effect on number of leaves. The maximum number of leaves was recorded under N_3 treatment (N@100kg/ha) while the minimum no. of leaves was recorded under control condition. It might be influenced by nitrogen fertilization which increases cytokinin production and cell growth and increases the number of leaves. The results of the present study are supported with the Ahmadi *et al.* (2010), Khalid and Shedeed, (2015) and Nigatu *et al.* (2019).

5.1.5. Biomass (fresh and dry weight basis)

The biomass yield in the present investigation has been significantly affected by the root pruning and nitrogen fertilization at all stages viz. 30, 60, 90, 120 and 150 DAP. The maximum fresh and dry weight was recorded in 12 cm pruned seedlings from the collar region (L_3). This might be due to the increase in auxin production in root pruned seedlings (Miller and Graves, 2019) which increases growth parameters (shoot length, root length, collar diameter and number of leaves per plant), which could have been responsible for increase in shoot, root and leaves biomass. These results are similar with the findings of Benson and Shephered (1977), Koon and O' Dell (1977) and Vasishth *et al*. (2007).

The application of nitrogen also had a significant effect on the fresh and dry weight of shoot, root and leaves. Nitrogen application up to 100kg N/ha showed increase in biomass. The application of nitrogen may results in the increase in carbohydrates production, proteins synthesis and other organic compounds, which might have increased the growth of plants and may be responsible for increase in shoot, root and leaves biomass. Similar findings were reported by Van dorssser and Rook (1972), Sanjeev, (1993), Liu *et al.* (2010), Luna *et al.* (2014), Yang and Fan (2012) and Zhang *et al*. (2017).

5.2. Physiological parameters of *Celtis australis*

5.2.1. White root regeneration

Root pruning had significant effects on white root regeneration at 30 to 150 DAP. The 12 cm root pruning (L_3) from the collar region showed the maximum white root regeneration which may encourage fibrous root system for better development of seedlings. This is due to the environmental factors which affect the root regeneration viz. relatively warm temperatures, good soil aeration, absence of water stress and relatively high light intensities. The age and physiological status of the plant also have an influence on white root regeneration, the younger the plant the higher the root regeneration potential (Geisler and Ferree, 1984). The similar finding was observed by Fuchigami and Moelle (1978) and Vasishth *et al*. (2007).

The different doses of nitrogen also had a significant effect on the white root regeneration. The maximum white root regeneration was recorded in N_3 while the minimum was recorded in control condition (N_1). This is due to the supply of fertilizers which can contribute to influence in root stimulation of seedlings and the process of root initiation in plants. The increase in auxin and cytokinin concentration in root xylem sap after 24 hours of root pruning has been

reported by Carlson and Larson (1977), which might have increased the root regeneration in seedings. This is line with the findings of Stone *et al*. (1962) in ponderosa pine, Nambiar *et al*. (1979) in *Pinus radiata*, radiate pine and douglas fir.

5.2.2. Survival percent (%)

The root pruned seedlings showed a significant effect on survival percent. The survival percent were reported highest in 12 cm root pruned seedlings from the collar region (L_3) while the lowest value was observed in control (L_1). This may be attributed to the root growth and fibrous root development which improves the root surface area and root-soil contact required for adequate water and nutrient absorption for plant growth thus, avoiding planting stress for ensuring plant survival. The similar observations were made by Singh *et al.* (1984) in *Picea smithiana*, Watson and Synder (1987) and Grossnickle, (2005).

The nitrogen fertilization also had a significant effect on survival percent. The survival percent has been found maximum in case of seedling applied with 100kg/ha (N_3). This might be due to the adding of nitrogen fertilizer increases the seedling size. The larger seedlings generally display a greater photosynthetic rate and have a higher net carbon gain which may increase the survival rate. The similar findings were observed by Jose *et al.* (2003), Gough and Seiler (2004) and Luis *et al.* (2009).

5.2.3. Chlorophyll content (‘a’ ‘b’ and total chlorophyll)

The root pruned seedlings showed a significant effect on chlorophyll content (‘a’ ‘b’ and total chlorophyll) at 60 and 120 DAP. The chlorophyll content were reported maximum in 12 cm root pruned seedlings which was statistically similar with 6 cm root pruned seedlings while the minimum value observed in

control. The chlorophyll contents were found maximum in root pruned seedlings due to residual effects which produced the highest significant content of chlorophyll (Yehia *et al*., 2014). Tognetti *et al*. (2013) revealed that the increased chlorophyll content is due to the higher sucrose content present in the seedling. The similar findings were also reported by Geisler and Ferree (1984) and Schupp and Ferree (1987).The similar results were also found by Angeles *et al*. (2008) in *Rosa hybrid*.

The nitrogen application also had a significant effect on chlorophyll content ('a', 'b' and total chlorophyll) with the maximum concentrations of chlorophyll recorded under N_3 while the minimum concentration of chlorophyll was recorded under N_1. This might be due to the addition of nitrogen promotes the formation of active photosynthetic pigments by increasing the amounts of stromal and thylakoid proteins in leaves (Filho *et al*., 2011) and chlorophyll and Carotenoid synthesis are also dependent upon mineral nutrition (Daughtry and Mcmurtey, 2000). Similar results were also observed by Shankar (1990), cooke *et al*. (2005), Tao *et al.* (2010) and Filho *et al.* (2011).

5.3. Nutritional parameters of *Celtis australis*

5.3.1. Nutrient content and uptake

Result obtained from the present investigation shows that NPK content and their uptake have significantly increased due to the root pruning and nitrogen fertilization at all stages of growth viz. 30, 60, 90, 120 and 150 DAP. The light pruned (12 cm from collar region) seedlings had higher content than severely pruned plants (6 cm from collar region). This might be due to the nutrients content and their uptake which depends upon the absorption capacity of roots, mass flow and diffusions of root. As the root system regenerates, uptake may increase accordingly. The efficiency of roots in uptake of nutrients depends on the

amount of surface in contact with soil and on the permeability of root surface. Root regeneration after root pruning provides more root branches which increases the absorbing surface. These factors suggest that uptake of nutrients will be the same or even improved when the root system is regenerated. The decrease in concentration and uptake of nutrients (NPK) in severely pruned seedling (6 cm) may be due to greater decrease in root biomass has affected the absorption capacity of root, which could have decreased xylem functioning, poor conductivity of the soil surrounding the roots, increase in the content resistance between soil and roots (Dhiman, 1991). The similar findings were reported by Vasishth *et al.* (2007) in *Acacia catechu*.

The nitrogen application also had a significant effect on NPK content and their uptake. With increasing nitrogen application, nitrogen content and their uptake has increased in the seedlings up to N_3 level (100kg N/ha) and decreased afterwards. Nitrogen content in plants increased due to the good availability of applied fertilizer for the whole growing period (Kaplan *et al.,* 2015). Increases in concentration of highly mobile elements such as P and K in stressed plants could be partly due to their absorption throughout the seasons (Mead, 1984). The similar findings were also reported by Bukovac and Wittwor (1975), Rao (1985), Koul (1987), Malik (1987), Sanjeev (1993), Singh and Sharma (2009), Rufat and Arbones (2010), Wang (2010), Dumroese *et al.* (2013) Verma and Chauhan (2013), Fang *et al.* (2017) and Steven *et al.* (2020).

CHAPTER 6 SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of root pruning and nitrogen application on growth performance and establishment of *Celtis australis* seedlings in Garhwal Himalaya"** has been carried out to study the effect of root pruning and nitrogen application on the survival and establishment of *Celtis australis* seedlings.

The experiment consisted of three root pruning length viz, control, 6 and 12 cm root pruning from the collar region and four nitrogen doses viz, 0Kg/ha, 50kg/ha, 100kg/ha and 150kg/ha were applied to *Celtis australis* seedlings. The summary of the results obtained during the course of investigation are mentioned below;

- The seedlings of 12cm (L_3) root pruned and nitrogen application at the rate of 100kg/ha (N_3) showed higher shoot length at 30 to 150 days after planting.
- Root length of *C. australis* seedlings at various stages (30DAP to 150DAP) showed the maximum length in 12 cm root pruned seedlings (L_3) and nitrogen application at the rate of 100kg/ha (N_3).
- The highest collar diameter of seedlings were recorded at 12 cm root pruned seedlings (L_3) and nitrogen application at the rate of 100kg/ha (N_3) with interaction of $L_3 \times N_3$ at 30 to 150 days after planting.
- The number of leaves of *C. australis* seedlings were found maximum at 12 cm root pruned seedlings (L_3) and nitrogen application of 100Kg/ha (N_3) from 30 to 150 days after planting.
- The values of fresh and dry weight of shoot, root and leaves were higher in similar treatment of L_3 and N_3 in all growth duration 30 days to 150 days after planting.

- Nitrogen application of 100Kg/ha and 12 cm pruned seedlings from collar region showed higher white root regeneration and their combination also showed higher yield from 30 to 150 days after planting.
- The maximum survival of seedlings was registered in 12 cm root pruned seedlings (L_3) and nitrogen at the rate of 100Kg/ha (N_3) whereas the interactions of $L_1 \times N_3$ and $L_3 \times N_3$ were recorded with high survival (98.00%) percentage at 150 days after planting.
- For chlorophyll content 'a', 'b' and total chlorophyll, the highest content were obtained in L_3 and N_3 treatment where as the minimum content was found under control condition. In case of interaction of both factor, the maximum content for chlorophyll 'a', 'b' and total chlorophyll were recorded in $L_3 \times N_4$ (12cm pruning from the collar region coupled with nitrogen applications at the rate of 150kg/ha) treatment at 60 and 120 days after planting.
- The highest concentration of NPK and their uptake were recorded in 12cm root pruned seedlings from collar region and nitrogen application at the rate of 100kg/ha. Also the interaction effect of 12 cm root pruned seedlings from collar region and nitrogen at the rate of 100Kg/ha excelled for NPK concentration and their uptake at most growth stages.

Conclusion:

Based on the results obtained from the present study, it may be concluded that root pruning modified morphophysiological characteristics of seedlings. The application of nitrogen also revealed significant influence on most of parameters and 100kg N/ha was considered best for the growth performance of the seedlings. The seedlings pruned at 12 cm from the collar region also induced the growth performance. Nitrogen application and root pruning combinations recovered the plants from the stress condition and enhanced the morphological as well as

physiological characteristics with maintaining the nutrient status. Seedlings pruned at 12cm and applied with 100kg N/ha recovered at the same time from the stress efficiently and also increased the survival percent with increase in root pruning length with the application of 100kg N/ha.

Since, the results of present investigation are taken for five months only, the investigation can be repeated for one or two years more for coming to valid & viable conclusion.

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APPENDICES

Appendix 1:- Metrological data observed during 2019 at Agromet Observatory, Ranichauri.

2019	Tmax (^{0}C)	Tmin (^{0}C)	Rainfall (mm)	RH Morning (%)	RH Afternoon (%)	Wind speed (kmph)	Sunshine (Hours)	Evaporation (mm)	Rainy days
July	23.4	15.3	175.6	93	82	2.0	4.2	1.9	14
August	23.4	15.4	172.2	95	81	2.6	4.2	1.8	11
September.	22.6	14.1	139.1	95	79	3.8	5.1	1.7	7
October.	20.0	8.8	27.9	85	68	2.8	7.1	1.5	1
November.	17.5	6.1	27.5	77	63	3.9	6.1	1.4	3
December.	12.8	0.6	61.1	78	62	4.1	6.2	0.8	2

Appendix 2:- Analysis of variance (ANOVA) for shoot length (cm) in *Celtis australis* at various growth stages.

		Shoot length														
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	254.389			268.722			268.722			286.889			286.889		
Factor L	2	299.181	149.590	3.859	323.514	161.757	4.152	323.514	161.757	4.152	312.181	156.090	4.015	312.181	156.090	4.015
Factor N	3	418.410	139.470	3.598	405.076	135.025	3.466	405.076	135.025	3.466	396.576	132.192	3.400	396.576	132.192	3.400
Interaction L X N	6	36.819	6.137	0.158	13.819	2.303	0.059	13.819	2.303	0.059	15.486	2.581	0.066	15.486	2.581	0.066
Error	22	852.778	38.763		857.111	38.960		857.111	38.960		855.278	38.876		855.278	38.876	

Appendix 3:-Analysis of variance (ANOVA) for root length (cm) in *Celtis australis* at various growth stages.

Root length															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	6.135			6.135			6.135			14.608			19.274		
Factor L	2	601.323	300.661	57.858	601.323	300.661	57.858	601.323	300.661	57.858	515.628	257.814	40.751	503.378	251.689	31.369
Factor N	3	139.977	46.659	8.979	139.977	46.659	8.979	139.977	46.659	8.979	184.839	61.613	9.739	226.158	75.386	9.396
Interaction L X N	6	53.163	8.861	1.705	53.163	8.861	1.705	53.163	8.861	1.705	26.635	4.439	0.702	19.441	3.240	0.404
Error	22	114.323	5.196		114.323	5.196		114.323	5.196		139.184	6.327		176.517	8.024	

Appendix 4:- Analysis of variance (ANOVA) for white root regeneration in *Celtis australis* at various growth stages.

White root regeneration																
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	52.597			52.597			77.542			77.542			77.542		
Factor L	2	1,117.347	558.674	72.697	1,117.347	558.674	72.697	896.542	448.271	62.106	896.542	448.271	62.106	896.542	448.271	62.106
Factor N	3	200.910	66.970	8.714	200.910	66.970	8.714	261.632	87.211	12.083	261.632	87.211	12.083	261.632	87.211	12.083
Interaction L X N	6	187.819	31.303	4.073	187.819	31.303	4.073	302.181	50.363	6.978	302.181	50.363	6.978	302.181	50.363	6.978
Error	22	169.069	7.685		169.069	7.685		158.792	7.218		158.792	7.218		77.542		

Appendix 5:- Analysis of variance (ANOVA) for collar diameter (cm) in *Celtis australis* at various growth stages.

Collar diameter															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.018			0.019			0.006			0.003			0.003		
Factor L	2	1.171	0.586	146.253	1.162	0.581	146.060	1.054	0.527	150.166	0.994	0.497	207.725	0.994	0.497	207.763
Factor N	3	0.151	0.050	12.552	0.153	0.051	12.777	0.142	0.047	13.453	0.418	0.139	58.209	0.418	0.139	58.221
Interaction L X N	6	0.305	0.051	12.682	0.305	0.051	12.795	0.284	0.047	13.489	0.214	0.036	14.899	0.214	0.036	14.901
Error	22	0.088	0.004		0.088	0.004		0.077	0.004		0.053	0.002		0.053	0.002	

Appendix 6:- Analysis of variance (ANOVA) for no. of leaves in *Celtis australis* at various growth stages.

No. of leaves															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	5,461.16			5,159.38			5,159.38			4,230.38			4,230.38		
Factor L	2	3,549.54	1,774.771	3.609	5,329.05	2,664.528	6.433	5,329.05	2,664.528	6.433	4,471.72	2,235.861	5.164	4,471.72	2,235.861	5.164
Factor N	3	14,695.57	4,898.525	9.960	13,885.94	4,628.648	11.176	13,885.94	4,628.648	11.176	14,589.05	4,863.019	11.232	14,589.05	4,863.019	11.232
Interaction L X N	6	13,665.73	2,277.623	4.631	14,285.55	2,380.926	5.749	14,285.55	2,380.926	5.749	13,243.11	2,207.185	5.098	13,243.11	2,207.185	5.098
Error	22	10,819.66	491.803		9,111.77	414.172		9,111.77	414.172		9,524.77	432.944		9,524.77	432.944	

Appendix 7:- Analysis of variance (ANOVA) for fresh weight of shoot in *Celtis australis* at various growth stages.

Fresh weight of shoot															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.111			1.306			0.107			0.098			0.115		
Factor L	2	6.473	3.236	4.785	52.126	26.063	29.826	63.740	31.870	38.027	66.747	33.374	37.895	65.771	32.886	36.514
Factor N	3	33.199	11.066	16.362	34.702	11.567	13.237	39.449	13.150	15.690	40.485	13.495	15.323	39.353	13.118	14.565
Interaction L X N	6	27.231	4.539	6.710	35.824	5.971	6.833	37.778	6.296	7.513	40.587	6.764	7.681	41.995	6.999	7.771
Error	22	14.880	0.676		19.225	0.874		18.438	0.838		19.375	0.881		19.814	0.901	

Appendix 8:- Analysis of variance (ANOVA) for dry weight of shoot in *Celtis australis* at various growth stages.

Dry weight of shoot															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.634			1.126			1.121			1.121			1.226		
Factor L	2	7.521	3.761	10.957	6.927	3.463	9.415	6.939	3.470	9.418	6.939	3.469	9.417	8.294	4.147	10.847
Factor N	3	7.113	2.371	6.908	5.974	1.991	5.413	5.977	1.992	5.408	5.976	1.992	5.407	7.889	2.630	6.878
Interaction L X N	6	7.234	1.206	3.513	7.843	1.307	3.553	7.861	1.310	3.556	7.861	1.310	3.556	6.271	1.045	2.734
Error	22	7.551	0.343		8.093	0.368		8.105	0.368		8.105	0.368		8.411	0.382	

Appendix 9:- Analysis of variance (ANOVA) for fresh weight of root in *Celtis australis* at various growth stages.

Fresh weight of root															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	6.161			6.682			6.303			5.790			5.181		
Factor L	2	14.758	7.379	8.255	12.781	6.391	6.740	13.031	6.515	6.950	12.242	6.121	5.776	11.393	5.697	5.420
Factor N	3	11.358	3.786	4.236	11.874	3.958	4.175	11.507	3.836	4.092	11.032	3.677	3.470	10.719	3.573	3.399
Interaction L X N	6	14.840	2.473	2.767	17.592	2.932	3.092	17.720	2.953	3.150	16.967	2.828	2.668	19.007	3.168	3.014
Error	22	19.664	0.894		20.859	0.948		20.623	0.937		23.315	1.060		23.123	1.051	

Appendix 10:- Analysis of variance (ANOVA) for dry weight of root in *Celtis australis* at various growth stages.

Dry weight of root															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.442			2.850			2.685			2.686			2.876		
Factor L	2	4.385	2.193	7.958	10.052	5.026	14.962	6.466	3.233	21.925	6.467	3.233	21.932	11.081	5.540	17.479
Factor N	3	6.256	2.085	7.568	3.630	1.210	3.603	1.351	0.450	3.054	1.351	0.450	3.056	6.345	2.115	6.672
Interaction L X N	6	9.639	1.606	5.830	5.559	0.926	2.758	5.878	0.980	6.643	5.877	0.980	6.644	9.048	1.508	4.757
Error	22	6.062	0.276		7.390	0.336		3.244	0.147		3.244	0.147		6.974	0.317	

Appendix 11:- Analysis of variance (ANOVA) for fresh weight of leaves in *Celtis australis* at various growth stages.

Fresh weight of leaves															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	3.229			6.091			8.647			8.646			8.627		
Factor L	2	7.002	3.501	4.545	10.326	5.163	7.427	14.458	7.229	9.467	14.457	7.229	9.466	14.540	7.270	9.473
Factor N	3	17.028	5.676	7.369	6.908	2.303	3.313	10.942	3.647	4.776	10.941	3.647	4.775	10.881	3.627	4.726
Interaction L X N	6	27.220	4.537	5.890	44.967	7.495	10.782	40.148	6.691	8.762	40.149	6.691	8.762	40.133	6.689	8.715
Error	22	16.944	0.770		15.292	0.695		16.800	0.764		16.801	0.764		16.884	0.767	

Appendix 12:- Analysis of variance (ANOVA) for dry weight of leaves in *Celtis australis* at various growth stages.

Dry weight of leaves															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.105			0.443			2.343			3.389			3.313		
Factor L	2	0.304	0.152	14.845	3.680	1.840	6.167	5.365	2.682	5.801	3.389	1.694	6.271	4.076	2.038	7.559
Factor N	3	0.250	0.083	8.148	4.413	1.471	4.930	4.905	1.635	3.536	3.639	1.213	4.489	3.819	1.273	4.723
Interaction L X N	6	1.587	0.265	25.868	5.382	0.897	3.007	17.491	2.915	6.304	18.611	3.102	11.480	20.214	3.369	12.498
Error	22	0.225	0.010		6.564	0.298		10.173	0.462		5.944	0.270		5.931	0.270	

Appendix 13:- Analysis of variance (ANOVA) for survival percent (%) and Chlorophyll "a" in *Celtis australis* at various growth stages.

Survival percent (%)					Chlorophyll " a"					
		150DAP			30DAP			60DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	56.000			0.002			0.777		
Factor L	2	598.500	299.250	74.813	0.020	0.010	20.439	5.427	2.713	21.526
Factor N	3	378.750	126.250	31.563	0.007	0.002	5.074	26.705	8.902	70.621
Interaction L X N	6	691.500	115.250	28.813	0.022	0.004	7.663	60.725	10.121	80.293
Error	22	88.000	4.000		0.002			0.777		

Appendix 14:- Analysis of variance (ANOVA) for Chlorophyll "b" and total chlorophyll in *Celtis australis* at various growth stages.

Chlorophyll " b"								Total chlorophyll					
		30DAP			60DAP			30DAP			60DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.028			6.905			0.726			11.174		
Factor L	2	2.738	1.369	29.584	136.163	68.082	22.660	2.132	1.066	51.160	103.923	51.962	47.966
Factor N	3	0.645	0.215	4.647	32.901	10.967	3.650	0.508	0.169	8.118	24.341	8.114	7.490
Interaction L X N	6	1.248	0.208	4.496	193.110	32.185	10.712	0.970	0.162	7.756	151.923	25.320	23.374
Error	22	1.018	0.046		66.099	3.004		0.458	0.021		23.833	1.083	

Appendix 15:- Analysis of variance (ANOVA) for nitrogen concentration in *Celtis australis* at various growth stages.

Nitrogen concentration															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.010			0.001			0.597			0.008			0.001		
Factor L	2	0.120	0.060	21.979	0.024	0.012	12.546	3.026	1.513	13.980	0.088	0.044	84.823	4.955	2.477	5,242.530
Factor N	3	0.028	0.009	3.451	0.564	0.188	194.110	1.146	0.382	3.530	0.064	0.021	41.159	0.154	0.051	108.970
Interaction L X N	6	0.343	0.057	20.953	0.522	0.087	89.942	3.790	0.632	5.837	0.707	0.118	226.208	0.873	0.145	307.770
Error	22	0.060	0.003		6.564	0.298		2.381	0.108		0.011	0.001		0.010	0.000	

Appendix 16:- Analysis of variance (ANOVA) for nitrogen uptake in *Celtis australis* at various growth stages.

Nitrogen uptake																
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.004			0.004			0.003			0.003			0.004		
Factor L	2	268.594	134.297	497,900.179	361.370	180.685	654,726.396	13,225.975	6,612.988	28,070,228.170	673.794	336.897	1,008,408.319	16,175.418	8,087.709	38,265,182.403
Factor N	3	307.416	102.472	379,910.843	1,614.461	538.154	1,950,040.690	6,156.544	2,052.181	8,710,919.105	344.235	114.745	343,457.331	3,435.751	1,145.250	5,418,494.661
Interaction L X N	6	1,401.685	233.614	866,114.165	3,776.178	629.363	2,280,544.499	23,272.536	3,878.756	16,464,201.970	2,731.672	455.279	1,362,750.282	10,682.280	1,780.380	8,423,468.609
Error	22	0.004			0.006	0.000		0.005	0.000		0.007	0.000		0.005	0.000	

Appendix 17:- Analysis of variance (ANOVA) for phosphorus concentration in *Celtis australis* at various growth stages.

Phosphorus concentration															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000			0.001			0.001			0.002			0.000		
Factor L	2	0.090	0.045	104.523	0.030	0.015	27.828	0.044	0.022	40.446	0.068	0.034	16.117	0.001	0.001	1.265
Factor N	3	0.053	0.018	40.745	0.015	0.005	9.454	0.072	0.024	44.188	0.108	0.036	17.066	0.028	0.009	22.864
Interaction L X N	6	0.136	0.023	52.206	0.036	0.006	11.208	0.054	0.009	16.636	0.792	0.132	62.431	0.041	0.007	16.601
Error	22	0.010	0.000		0.012	0.001		0.012	0.001		0.047	0.002		0.009	0.000	

Appendix 18:- Analysis of variance (ANOVA) for phosphorus uptake in *Celtis australis* at various growth stages.

Phosphorus uptake																
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.002			0.002			0.000			0.003			3.092		
Factor L	2	177.043	88.521	263,117.439	239.486	119.743	334,590.377	99.549	49.774	107,207.120	168.451	84.226	293,180.503	120.565	60.283	52.611
Factor N	3	47.321	15.774	46,885.567	73.892	24.631	68,823.722	133.324	44.441	95,720.526	427.719	142.573	496,281.317	161.462	53.821	46.971
Interaction L X N	6	1,849.238	308.206	916,101.692	1,324.947	220.825	617,036.126	1,444.503	240.751	518,542.067	3,641.141	606.857	2,112,402.727	1,340.425	223.404	194.974
Error	22	0.007	0.000		0.008	0.000		0.010	0.000		0.006	0.000		25.208	1.146	

Appendix 19:- Analysis of variance (ANOVA) for potassium concentration in *Celtis australis* at various growth stages.

Potassium concentration															
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.000			0.002			0.002			0.001			0.025		
Factor L	2	0.783	0.392	1,684.515	3.495	1.748	36.414	4.033	2.017	1,462.924	0.094	0.047	79.244	2.836	1.418	19.315
Factor N	3	2.279	0.760	3,267.835	2.120	0.707	14.725	0.875	0.292	211.528	1.690	0.563	951.422	3.041	1.014	13.809
Interaction L X N	6	6.120	1.020	4,386.919	3.505	0.584	12.173	4.063	0.677	491.219	1.771	0.295	498.597	1.786	0.298	4.055
Error	22	0.005	0.000		1.056	0.048		0.030	0.001		0.013	0.001		1.615	0.073	

Appendix 20:- Analysis of variance (ANOVA) for potassium uptake in *Celtis australis* at various growth stages.

Potassium uptake																
		30DAP			60DAP			90DAP			120DAP			150DAP		
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.035			1.073			0.001			0.006			0.385		
Factor L	2	5,599.382	2,799.691	1,234,083.031	12,196.224	6,098.112	11,765.581	36,384.577	18,192.289	105,823,405.661	379.951	189.976	857,023.390	12,819.952	6,409.976	32,605.016
Factor N	3	9,534.956	3,178.319	1,400,979.406	935.618	311.873	601.721	5,261.185	1,753.728	10,201,328.002	5,855.925	1,951.975	8,805,801.718	9,879.082	3,293.027	16,750.330
Interaction L X N	6	45,130.618	7,521.770	3,315,540.539	18,185.110	3,030.852	5,847.667	23,019.588	3,836.598	22,317,251.130	7,289.979	1,214.996	5,481,124.244	15,271.546	2,545.258	12,946.720
Error	22	0.050	0.002		11.403	0.518		0.004	0.000		0.005	0.000		4.325	0.197	

VITAE

The author, Ms. Pooja Uniyal was born on 21 August 1997 at New Tehri, District Tehri Garhwal (Uttarakhand). She has passed High school and Intermediate examination in 2012 and 2014, respectively from Uttarakhand Board. Later on, she passed B.Sc. (CBZ) from P.G college New tehri, (Uttarakhand) affiliated by H.N.B Garhwal University in year 2017. She was admitted to College of Forestry, Ranichauri, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Bharsar in 2017 to pursue her post-graduation studies in M.Sc. forestry with specialization in Silviculture.

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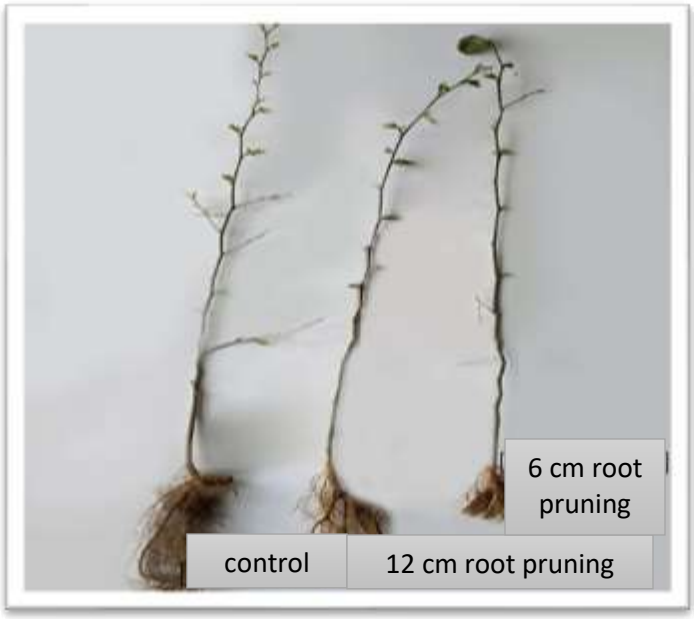
Plate 3.1: An overview of field experimental trial



A: Root pruning length

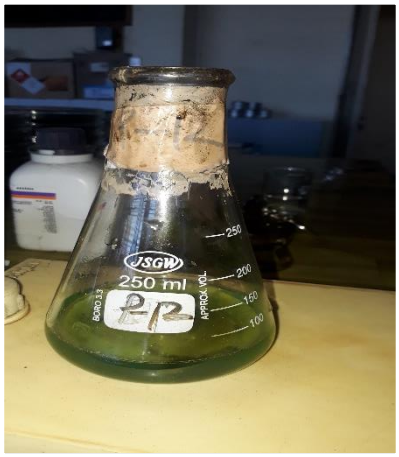
B: Root pruning at transplanting

C: Transplanting shock after pruning

Plate 3.2 An overview of root pruning and transplanting of *Celtis australis* seedlings

A: Sample for Nitrogen digestion

B: Kjeldahal distillation unit



C: Green color indicates presence of nitrogen

D: Sample for Chlorophyll content

E: Digestion of phosphorus sample on hot plate

F: Phosphorus test after digestion

Plate 3.3: Assessment of nitrogen, phosphorus and chlorophyll content in *Celtis australis* seedlings