EFFECT OF NITROGEN APPLICATION ON GROWTH, BIOMASS AND QUALITY OF *Salix alba* NURSERY STOCK

Thesis

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

MASTER OF SCIENCE
in
FORESTRY AND NATURAL RESOURCES
(Minor Subject: Soil Science)

By
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(L-2013-A-56-M)

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CERTIFICATE I

This is to certify that the thesis entitled, "**Effect of nitrogen application on growth, biomass and quality of *Salix alba* nursery stock**" submitted for the degree of M.Sc. in the subject of **Forestry** (Minor subject: **Soil Science**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Sirtaj Singh (L-2013-A-56-M)** under my supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled, "**Effect of nitrogen application on growth, biomass and quality of *Salix alba* nursery stock**" submitted by **Sirtaj Singh (L-2013-A-56-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of M.Sc in the subject of **Forestry** (Minor subject: **Soil Science**) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same.

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ABSTRACT

Willows are very important tree species for the ecology and economy of countries in temperate and subtropical zones of the world. The field trials on *Salix alba* were conducted during 2015-16 in nursery area of Department of Forestry and Natural Resources, PAU, Ludhiana. The experiment was laid out in randomized block design with three replications, to study the effect of cutting size and nitrogen fertilizer on nursery stock of *Salix alba.* The data for plant height, collar diameter, number of branches, shoot biomass, root biomass, stock vigour index, sturdiness quotient and NPK level in soil and plant was recorded. Results revealed that with increasing rate of nitrogen application, a significant and progressive increase in available nitrogen was noticed in both the cutting sizes which resulted in improved nitrogen content in foliage of *Salix alba*. A curvilinear relationship was observed when rates of nitrogen application were regressed with total biomass yield indicating that application of 150 kg N ha^{-1} was adequate to get optimum yield for both the cutting sizes. This signified that *Salix* responded significantly to N application @ 150 kg N ha^{-1} and resulted in 27.66 and 76.74 per cent increase in total biomass yield of 0.50-1.50 cm and 1.51-2.50 cm cutting sizes, respectively. The growth of *Salix* with cutting size of 1.51-2.50 cm was found to be more superior as compared to 0.50-1.50 cm cutting size. So it is concluded that cuttings size of 1.51-2.50 cm gave better performance in all growth parameters as compared to cuttings size of 0.50-1.50 cm. Results revealed that the stock vigour index increases when nitrogen doses from 50-200 kg N/ha were applied. The impact is more noticeable from 50-150 kg N/ha rather than 150-200 kg N/ha. It can be concluded from this study that application of 150 kg N ha^{-1} to *Salix* was adequate to get optimum total biomass yield for both the cutting sizes.

Keywords: Willow, cutting sizes, nitrogen, *Salix alba*

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Signature of Major Advisor	**Signature of the Student**

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ਸਾਰ ਅੰਸ਼

ਰੁੱਖਾਂ ਦੀਆਂ ਪ੍ਰਜਾਤੀਆਂ ਵਿੱਚੋਂ ਵਿਲੋ ਸੰਸਾਰ ਦੇ ਠੰਡੇ ਅਤੇ ਗਰਮਤਰ ਦੇਸਾਂ ਦੇ ਵਾਤਾਵਰਣ ਅਤੇ ਆਰਥਿਕਤਾ ਲਈ ਮਹੱਤਵਪੂਰਨ ਰੁੱਖ ਹੈ। ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੁਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਵਣ ਅਤੇ ਕੁਦਰਤੀ ਸੋਮੇ ਵਿਭਾਗ ਦੇ ਨਰਸਰੀ ਖੇਤਰ ਵਿੱਚ ਸੈਲਕਸ ਏਲਬਾ ਉੱਪਰ ਤਜ਼ਰਬਾ ਕੀਤਾ ਗਿਆ । ਕਲਮਾਂ ਦੇ ਆਕਾਰ ਅਤੇ ਨਾਇਟ੍ਰੋਜਨ ਦੇ ਸੈਲਿਕਸ ਏਲਬਾ ਦੀ ਨਰਸਰੀ ਉੱਪਰ ਪੈਂਦੇ ਪ੍ਰਭਾਵ ਨੂੰ ਜਾਨਣ ਲਈ ਰੈਂਡੋਮਾਇਜਡ ਬਲਾਕ ਡਿਜ਼ਾਇਨ ਵਿੱਚ ਤਜ਼ਰਬੇ ਨੂੰ ਤਿੰਨ ਵਾਰ ਦੁਹਰਾਇਆ ਗਿਆ। ਪੌਦੇ ਦੀ ਲੰਬਾਈ, ਕਾਲਰ ਵਿਆਸ, ਟਾਹਣੀਆਂ ਦੀ ਗਿਣਤੀ, ਸ਼ੂਟ ਦਾ ਜੈਵਿਕ ਮਾਦਾ, ਜੜ੍ਹਾਂ ਦਾ ਜੈਵਿਕ ਮਾਦਾ, ਸਟਾਕ ਵਿਗਰ ਇੰਡੈਕਸ, ਸਖ਼ਤਪਨ ਅਤੇ ਮਿੱਟੀ ਅਤੇ ਪੌਦੇ ਵਿੱਚ ਐਨ.ਪੀ.ਕੇ. ਦੇ ਪੱਧਰ ਬਾਰੇ ਆਂਕੜੇ ਇਕੱਠੇ ਕੀਤੇ ਗਏ। ਨਤੀਜਿਆਂ ਤੋਂ ਸਾਬਿਤ ਹੁੰਦਾ ਹੈ ਕਿ ਨਾਇਟ੍ਰੋਜਨ ਦੀ ਮਾਤਰਾ ਵਧਾਉਣ ਨਾਲ ਕਲਮਾਂ ਦੇ ਦੋਹਾਂ ਆਕਾਰਾਂ ਵਿੱਚ ਉਪਲਬਧ ਨਾਈਟ੍ਰੋਜਨ ਦਾ ਪੱਧਰ ਵੀ ਵਧਿਆ, ਨਤੀਜਨ ਸੈਲਿਕਸ ਐਲਬਾ ਦੇ ਪੱਤਿਆਂ ਵਿੱਚ ਨਾਈਟ੍ਰੋਜਨ ਵਧੀ। ਨਾਈਟ੍ਰੋਜਨ ਅਤੇ ਝਾੜ ਵਿੱਚ ਕਰਵੀਲੀਨੀਅਰ ਸੰਬੰਧ ਪਾਇਆ ਗਿਆ। ਜਿਸ ਮੁਤਾਬਿਕ ਦੋਨਾਂ ਕਲਮਾਂ ਦੇ ਆਕਾਰ ਦੇ ਸਹੀ ਝਾੜ ਲਈ 150 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ ਢੁੱਕਵੀਂ ਸੀ। ਸੈਲਿਕਸ ਨੇ 150 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ ਤੱਕ ਰਿਸਪਾਂਡ ਕੀਤਾ । ਜਿਸ ਕਰਕੇ 0.5-1.50 ਸੈਂਟੀਮੀਟਰ ਅਤੇ 1.5-2.5 ਸੈਂਟੀਮੀਟਰ ਆਕਾਰ ਦੀਆਂ ਕਲਮਾਂ ਦੇ ਕੁੱਲ ਜੈਵਿਕ ਮਾਦੇ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 27.66 ਅਤੇ 76.74 ਪ੍ਰਤੀਸ਼ਤ ਵਾਧਾ ਦਰਜ ਕੀਤਾ ਗਿਆ । ਇਹ ਦਰਸਾਉਂਦਾ ਹੈ ਕਿ 1.5-2.5 ਸੈਂਟੀਮੀਟਰ ਆਕਾਰੀ ਕਲਮ ਨੇ 0.5-1.50 ਸੈਂਟੀਮੀਟਰ ਆਕਾਰੀ ਕਲਮ ਤੋਂ ਵਿਕਾਸ ਦੇ ਸਾਰੇ ਹੀ ਮਾਪਦੰਡਾਂ ਵਿਚ ਵਧੀਆ ਕਾਰਗੁਜਾਰੀ ਦਿਖਾਈ। ਨਤੀਜੇ ਦਰਸਾਉਂਦੇ ਹਨ ਕਿ ਸਟਾਕ ਵਿਗਰ ਇੰਡੈਕਸ 50-200 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ ਤੱਕ ਵਧਿਆ। 50-150 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ ਤੱਕ ਪ੍ਰਭਾਵ 150-200 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅ੍ਰ ਦੇ ਮੁਕਾਬਲੇ ਜ਼ਿਆਦਾ ਪ੍ਰਤੱਖ ਸੀ। ਇਸ ਖੋਜ ਤੋਂ ਪਤਾ ਲੱਗਦਾ ਹੈ ਕਿ ਸੈਲਿਕਸ ਦੇ ਸਹੀ ਜੈਵਿਕ ਝਾੜ ਲਈ 150 ਕਿਲੋ ਨਾਈਟ੍ਰੋਜਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ ਦੋਨੋਂ ਆਕਾਰ ਦੀਆਂ ਕਲਮਾਂ ਲਈ ਢੁੱਕਵੀਂ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ :- ਵਿੱਲੋ, ਕਲਮ ਅਕਾਰ, ਨਾਈਟ੍ਰੋਜਨ, ਸੈਲਿਕਸ ।

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ	**ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

CONTENT

CHAPTER - I

INTRODUCTION

Crop diversification from rice-wheat has attracted the attention of government and farmers of Punjab due to continuous decrease in ground water table and pollution of soil/water. To promote diversification, major emphasis is placed on cultivation of maize, pulses, oil seed crops, vegetables, flowers, fruits and short rotation trees than traditional rice-wheat rotation. Agroforestry intercropping allows structural and functional diversification of agricultural systems. As the forest and tree cover in Punjab is only 6.50 per cent (Anonymous 2014), agroforestry is the only viable alternative, which is capable of meeting the prechallenges of forest area shortages, which is required under National Forest Policy 2016. It is an integrated land use approach, including cultivation of woody perennials in association with annual crops and holds immense potential to ensure stability and sustainability in production and to provide ecological and economic security as compared to conventional system of mono-cropping (Singh *et al* 1997). Government of Punjab has taken initiatives like "Green Punjab" mission to increase area under tree cover. Agroforestry, besides increasing area under tree outside forest will offer economic benefits to farmers and environment benefits to all. In Punjab, main tree species raised for agroforestry are *Populus, Eucalyptus* and *Melia*. But, an another species willow, which is multipurpose, fast growing and has lots of potential in sports industry, phytoremediation and biomass production can be introduced for farm forestry plantation under diverse climatic and edaphic conditions of Punjab. Species also holds potential for cultivation with rice, which is discouraged with poplar and has been recommended in irrigated and wetland conditions of sub-tropical climate (Saini and Singh 2001)

Short rotation woody crops (SRWC) (typically of *Salix* or *Populus* species) are a demonstrated biomass cropping system that is managed more intensively than usual forestry practices and harvested on a 3–4 year cycle (Verwijst 2001). Willows (*Salix* spp.) have exceptional potential for biomass production because of their rapid growth rates, coppicing ability, and large genetic variability and also controlled pollination and interspecific hybridization of willows is relatively easy to achieve compared with most forest tree genera (Zsuffa 1984). According to Christersson (1987) willow biomass production as high as 40 t ha^{-1} during one growing season has been achieved experimentally. Substantial efforts has been made in developed world to pursue research for improved short rotation Forestry plantation with willow for waste water treatment and soil reclamation (Christersson and Senneby- Forse 1994; Rosenquist *et al* 1997)

Willows are very important tree species for the ecology and economy of countries in temperate and subtropical zones of the world (Anonymous 2001). Willows belonging to the genus *Salix*, family Salicaceae, are light demanding deciduous trees and shrubs, found primarily on moist soils in cold and temperate regions of the northern hemisphere. About 350–500 species of willow (*Salix* spp.), mainly growing in the Northern Hemisphere, currently exist worldwide (Argus 1999). In the Indian Himalayan region, 24 species of Salix are found (Putto 2010). Out of these, 10 shrubby, indigenous species are *Salix acmophylla, Salix daphnoides, Salix denticulate, Salix flagellaris, Salix karelinii, Salix lindleyana, Salix oxycarpa, Salix pycnostachya, Salix tetrasperma and Salix wallichiana* (Troupe 1986). Willows provide a wide range of wood products (including industrial roundwood and poles, pulp and paper, reconstituted boards, plywood, veneer, sawn timber, packing cases, pallets and furniture), non-wood products (fodder, fuelwood) and services (shelter, shade, protection of soil, water, crops, livestock and dwellings). Willows have an important role in phytoremediation (i.e. taking up heavy metals to purify polluted soils) of degraded sites, rehabilitation of fragile ecosystems (including combating desertification) and forest landscape restoration. The willow trees are also very effective as windbreak strips for the agricultural crops (Foereid *et al* 2002). Establishing purpose-grown willow (*Salix* spp.) plantations as a renewable dedicated bioenergy and bioproduct feedstock is advantageous for numerous reasons, which include its easy propagation and fast-growing nature, along with important environmental benefits like providing a cleaner energy source relative to fossil fuels, acting as an effective vegetation filter for environmentally harmful compounds, and increasing biodiversity within the agricultural landscape (Main *et al* 2007)

Nitrogen (N) is considered to be the principal soil nutrient influencing willow plantation productivity (Weih and Nordh 2005). Hytonen (1996) stated that nitrogen (N) was probably the nutrient most likely to limit biomass production in short-rotation plantations established on mineral soils. The use of inorganic N fertilizers have been used extensively for several decades, in attempts to promote the successful establishment and growth of planted willow but, the reported growth response of numerous willow varieties to added fertilizer N when grown under field conditions has been inconsistent, thereby precluding definitive relationships (i.e., calibrated fertilizer recommendations) between applied fertilizer N rates and subsequent willow biomass yields from being developed and applied universally (Hangs *et al* 2012). Hytonen (1994) reported that biomass yield of willow increased when fertilized with N while Hytonen (1995) recorded increased yield by 1.5–2.7 times compared to control plots after N fertilization. Substantial increases in plant biomass were also reported by Weih and Nordh (2002) when the N supply was increased from 20 to 120 kg N/ha. Excess nitrogen makes this species fast-growing, reflected by an average foliar N:P ratio >10, and more susceptible for watermark disease, indicated by an average foliar N:Ca ratio exceeding 1.5 (Bruno 2007). Direct effects of excess N can be a nutrient imbalance that disturbs plant growth (Van den Driessche 1974). Merilo *et al* (2006) found that fertilization of willow plantations increased the proportion of non-photosynthetic N in the leaves. Excessive fertilization may indirectly promote pathogenesis by increasing the amount of non-incorporated amino acids that circulate in the wood and enhancing Bs growth, which is a critical step in the pathogenesis (Huvenne 2007).

Work done on *Salix* in Punjab is inadequate scanty on the proposed topic. Department of Forestry and Natural Resources have initiated introduction of promising clones from different sources for their testing under farm forestry. Nursery stock of good quality is essentially required, so that it can be provided to farmers of Punjab for better willow timber production. In easy to root species, any type of cutting can be raised (Chmelar 1973) but for good quality stock appropriate size standardization is essential. Usually planting stock quality increases with size of cutting (Length as well as diameter). Intensive management of cuttings including nitrogen fertilization is important intervention for producing good quality nursery stock.

Present investigations were conducted to notify the effect of cutting size and nitrogen fertilizer on nursery stock of *Salix alba*

i) To study the growth of *Salix* in response to cutting size and nitrogen fertilization in the nursery.

ii) To study the impact of nitrogen doses on planting stock vigour.

CHAPTER-II

REVIEW OF LITERATURE

The review of literature provides basis for preparing the research proposal and conceptualization of different ideas given by different researchers. Presently no systematic plantation of *Salix* has been raised in Punjab, including no work on planting stock nutritional requirement for intended growth. Nitrogen fertilization and irrigation are common management practices to increase willow growth rates (Larsson *et al* 1998). The effects of N-fertilization on growth of *Salix* spp depend not only on the absolute quantity of N-application but on fertilization regime and site characters i.e., soil type, climate, number of applications, irrigation (Alriksson *et al* 1997). However, more relevant literature irrespective of *Salix* spp. has been reviewed in this chapter under two aspects:

2.1 Cutting size

2.2 Nitrogen fertilization

2.1 Cutting size

The size of the cuttings in respect of length and diameter play a great role in the establishment and growth of the plants. In hybrid poplar clone NF 338 (*Populus maxmowiezii* x *P. trichocarpa*) shoot elongation and dry shoot weight are strongly correlated and dry root weight somewhat less strongly correlated with the mid-diameter of the cutting, however, the correlation of total height with the diameter of cuttings was low at the end of the first and second growing season (Bowerso 1971). Singh (1974) reported that the longer cuttings (50 cm) of *Populus deltoides* gave significantly better height and diameter growth as compared to 40, 30 and 20 cm long cuttings. Lohani (1976) recorded that cuttings of 3 and 4 cm diameter gave the best growth and survival for all the three poplars, viz. *Populus deltoides* IC, Populus x *euramericana* '72/58' and '65/27'. Bozarczuk (1977) performed experiments with *Populus* alba, *P. canescens* and *P. tremula* and observed best results with cuttings 5-8 cm long with atleast one leaf and two buds from the middle of the long shoots.

Food and Agricultural Organization (FAO) in 1979 recommended that in general cuttings of 23 cm length and a diameter of 10-20 mm at mid point should be used. On shallow soils shorter cuttings (15-20 cm) should be used, while on deeper soils longer cuttings (50-80 cm) give the best results.

Long cuttings (18-20 cm) with diameter 1-3 cm taken from the main shoots in *Populus ciliata* gave the good results (Chaturvedi 1981). Deol and Khosla (1983) suggested direct field planting of large sized *Populus ciliata* cuttings (mid diameter 18 mm, length 30 cm) on moisture rich sites. For clonal propagation they recommended the cuttings with 22.5 cm length and 14 mm diameter at mid point. Singh and Chaukiyal (1983) in their study to determine the effect of diameter of cuttings on the establishment and growth of *Populus* *ciliata* found that thicker cuttings are better than thinner cuttings. They recommended the cuttings diameter of 15-25 mm for better success. Mathur *et al* (1983) reported that the length of the cuttings in *Populus* x *euramericana* '72/58' should not be less than 20 cm and the thickness should preferably be around 1.5 cm.

Basal diameter and height growth significantly increased with the increase in cutting diameter in *Populus koreana* x *Populus nigra* var. *italica* (Koo *et al* 1986). Chaukiyal *et al* (1987) recommended that the plant height and basal diameter in *Populus ciliata* increased with increase in diameter of the cuttings. Survival and branchiness also generally increased with diameter of cuttings. Rossi (1991) concluded that the longer cuttings in hybrid poplar had higher rates of survival and dry biomass production. In *Populus deltoides* survival was best in the two bud cuttings (79.0%) and least in the one bud cuttings (29%). Same pattern was observed for *P. ciliata* (Mughal and Khullar 1994, Rana *et al* 1995). Robinson and Raffa (1996) studied the importance of cuttings diameter and method of production on early growth of hybrid poplar. They concluded that hardwood cuttings diameter was not an indicator of tree vigour for 8 of 15 hybrid poplar clones tested and only a weak indicator for the remaining 7 clones. Bhrot (1995) reported strong positive relationship of cutting thickness with the secondary and tertiary roots.

Sidhu *et al* (1997) and Anon (1997) recommended cuttings with 2-3 cm diameter and 20-25 cm length with four live buds for nursery propagation in poplar. However, cuttings ranging from 1.5-3.0 cm in diameter and 18-25 cm in length are generally used.

Chauhan *et al* (2012) and Thakur *et al* (2013) recorded improvement in stock quality with increase in diameter in poplar cuttings.

2.2 Nitrogen fertilization

Biomass production of a *Salix* spp. at the German short rotation plantation at Abbachhof (ABB) was strongly increased by fertilization with 100 kg N ha^{-1} $year^{-1}$ (Hofmann-Schielle *et al* 1999) and mycorrhizal colonization on *Salix viminalis* is known to increase biomass production (Backhaus *et al* 1986). Baum *et al* (2002) investigated the effects of nitrogen fertilization (100, 200 kg N ha^{-1} $year^{-1}$) and soil properties on mycorrhizal formation on *Salix viminalis* at three short rotation plantations on Gleysols and Cambisols (Abbachhof (ABB) and Wildeshausen (WIL) in Germany, Ultuna (ULT) in Sweden) and observed that the quality and magnitude of the fertilization effects on mycorrhizal formation on *Salix viminalis* varied due to the soil properties, i.e. soil texture, soil N content and pH. The soil properties have been shown to modify the effects of fertilization on ectomycorrhizal colonization and VAM spore density in *Salix viminalis*. Therefore, in management practice of short rotation plantations, the benefit of N-fertilization should be evaluated keeping secondary effects caused by changed mycorrhizal formations in mind.

Farmer *et al* (1969) found that both nitrogen and phosphorus stimulated growth during the first 2 years after planting but phosphorus was effective only when combined with nitrogen fertilization. During this period, loose application of nitrogen fertilizer gave better results than bagged application and after 5 years, only nitrogen effects were statistically significant; mean height (2.59 m) of trees in the most effective nitrogen treatment (672 kg/ha) was 80% greater than controls.

Ari *et al* (1988) studied the effect of spacing and nitrogen fertilization on the establishment and biomass production of short rotation poplar in Finland and mentioned that thicker cuttings grew better whilst those of less than 1 cm diameter grew only moderately. Nitrogen fertilization improved height and diameter growth and above-ground dry mass yield. Woody biomass production was 4.2, tons ha^{-1} $year^{-1}$, at 300 kg/ha nitrogen. Brown *et al* (2005) found that through four growing seasons, fertilization with N as ammonium sulphate increased stem volume by an average of 65%, dbh by 22%, and height by 17% and additions of Ammonium sulphate increased foliar N, S and Cu concentrations in all clones. Sara *et al* (2007) reported that CO_2 enrichment reduced foliar nitrogen and increased the concentration of magnesium; whereas nitrogen fertilization had opposite effects on leaf nitrogen and magnesium concentrations. Moreover, the interaction between elevated CO_2 and N fertilization amplified some element unbalances such as the K/N-ratio.

Katherine *et al* (1994) examined the growth and nutrient use efficiency for red pine *(Pinus resinosa* Ait.) seedlings grown at various levels of light, nitrogen, and phosphorus. Nutrient use efficiency was estimated for nitrogen (NUE) and phosphorus (PUE) and was calculated as biomass production divided by total nutrient content. Seedlings grown in high light had four to five times more biomass than those in the low light treatment. Nitrogen supply had a significant effect on total biomass as well as other biomass components. Phosphorus supply did not had a significant effect on any of the biomass components. NUE and PUE decreased with increased supply of N and P, respectively. The results of this study suggest that red pine seedlings can adjust their nutrient use efficiency, particularly for N, when light and nutrient availability are varied. NUE was highest with high light and low N-high P supply in nutrient solutions.

The data of six independent fertilization experiments conducted between 1997 and 2003 in six Mediterranean forest species i.e, three oaks (*Quercus suber* L., *Q. ilex* L., and *Q. coccifera* L.), and three conifer (*Pinus pinea* L., *P. halepensis* Mill., and *Juniperus thurifera* L.) were reviewed by Salvalor *et al* (2005). Plants were cultivated under two contrasting N fertilization regimes and at the end or during the cultivation period several parameters related to drought and frost resistance were measured. N fertilization affected more the morphological than the physiological characters. N fertilization reduced frost hardiness in *Pinus* species and increased the osmotic potential both at full turgor and at turgor loss point in *J. thurifera*. High-fertilized seedlings in all species were larger and had greater shoot to root mass ratio than low-fertilized or unfertilized seedling.

Kannur and Devar (2003) conducted experiment at the Silviculture Nursery, College of Forestry, Sirsi, eight-month -old seedlings of teak raised in beds were used for the preparation of stump of sizes 1-2 cm of collar diameter with 2cm of shoot length and 15 cm root length. Stumps were planted in the polythene bags of 25 x 15 cm containing soil medium consisting of soil, sand and FYM in a ratio of 1:1:2. The experiment was replicated four times with 40 polythene bags, thereby 10 polythene bags per treatments were laid incompletely randomized design. There were six treatments and fertilizers were applied in the form of urea (46% N), rock phosphate (20% P_2O_5) and Muriate of potash (60% K_2O). After 60 days, treatments showed significant differences, one gram nitrogen per bag exhibited superior growth than other treatments. Similar trend was observed till 120 days.

Heiskanen *et al* (2009) examined the seedling development *of Silva Fennica* for three years at two contrasting soil fertility levels on a sandy test field in two planting years and on one natural forest out planting site in central Finland. Nutrient loading showed increase in shoot and root growth in a poor fertility soil during the first growing season after planting, while, after the first growing season, nutrient loading did not affect seedling performance. Although nutrient loading cannot compensate for the availability of nutrients to the seedlings from the soil, it may provide an additional input for fast plantation establishment on poorer sites during the first crucial growing season after out planting.

Kula *et al* (2012) studied the effects of stress caused by differentiated inputs of nitrogen after the application of ammonium nitrate (NH_4NO_3) on silver birch (*Betula pendula Roth*). The applied ammonium nitrate did not affect pH values but increased differently the content of nitrogen in soil and leaves. With increased inputs of nitrogen, the height and diameter increment of birch decreased, bud break was delayed and the autumn leaf-fall slowed down. Frost heaving of shoots occurred particularly in the lower half of the birch stem. With the increasing content of nitrogen in leaves, the content of phosphorus decreased and the level of potassium increased.

Weih and Nordh (2002) studied the effect of nitrogen in terms of growth in fourteen clones of willow (*Salix* spp.) under different fertilization treatments. Cuttings of willow clones, some commercially introduced and others new material, were pot-grown outdoors in Central Sweden under four experiment treatments in a full-factorial design. The experiment covered the period from bud-break until leaf abscission and the experimental conditions included two fertilization treatments. The growth of the clones were evaluated in terms of relative growth rate and total biomass production of whole plants and shoots. The nitrogen effect was studied in terms of N productivity, N accumulation and N losses by leaf abscission. Significant differences between clones were found in nearly all parameters measured and the clones varied in the responses to the experimental treatments (clone* factor interaction effects). The results are discussed with respect to clone selection for different willow applications such as biomass production and phytoremediation and willow growth performance under different nutrient availabilities.

In Turkey, growth characteristics and wood properties such as height, diameter, volume increment, basic density, dry matter, calorific value, ash content, nitrogen and protein values of fifty three willow clones with check-poplar clone I-214 were estimated on the basis of nursery performance by Tunctaner (2002). Some willow clones showed better growth performance than poplar clones.

Li *et al* (2011) examined responses of one- and two- year-old bare-root Olga Baylarch (*Larix olgensis* Henry) seedlings to nursery nitrogen supplements and subsequent one-year field performance on a competitive site. The fertilizer levels (kg N ha^{-1}) were 0 (control), 60 (conventional fertilization), 120 (additional nitrogen applied two times), 180 (additional nitrogen applied three times) and N were applied in increments of 30 kg ha^{-1} at 15-day interval to maintain a base nutrient level. Although pre-planting morphological attributes and nitrogen status of one-year-old seedlings were more sensitive to 60 Kg N than for two-year-old seedlings, the conventional application failed to enhance their field survival (15.6% vs 17.8%), relative height growth (89.0% vs 79.6%), and relative diameter growth (17.0% vs 22.9%). The one year old seedling's field survival (15.6% for 0, 17.8% for 60 Kg N) and 2 year old seedling's relative height growth rate (11.0% for 0, 8.9% for 60 Kg N) were not increased significantly until they were provided the 120 Kg N (survival of 23.3% for 1 year, relative height growth rate of 15.0% for 2 year old seedling). According to pre-planting attributes and field performance, optimum nursery nitrogen application was 120 Kg N for the 2 year old seedlings and 180 Kg N for 1 year old seedlings. Except for component nitrogen concentration, pre-planting morphological attributes and component N content for the 2 year old seedlings were as much 3.3 to 37.7 times that of 1 year old seedlings. In conclusion, the contrasting survival of poor (15.6%-28.9%) for 1 year old seedlings and high (84.4%-91.1%) for 2 year old seedlings indicated that additional nitrogen fertilizer would not equal the benefits of an another year's growth in the nursery. Successful reforestation could not be fulfilled by 1 year old seedlings regardless of their pre-nutrients. An alternative technique for sites with competing vegetation was to apply 120kg N ha^{-1} in the nursery during July and August on 2 year old seedlings.

Booth *et al* (2008) studied the replacing agricultural crops with short rotation woody species such as hybrid poplar trees. The objectives of this project were to evaluate a suitable planting stock for hybrid poplar, the effect of nitrogen (N) fertilizer application and pruning on hybrid poplar growth, and the response of four hybrid poplar clones to fertilizer application and their suitability in the boreal transition ecoregion of Saskatchewan. Trees grown from planting stock without roots had survival rates between 32-37%, whereas, the survival of trees with roots at the time of planting ranged from 62-81% after two years of growth. Trees that were planted as a rooted stock were 3.5 to 4.2 times greater in height and 4.0 to 5.6 times greater in root collar diameter than trees planted as an un-rooted stock type. The application of N fertilizer decreased tree volumes by 31% at the Alfalfa site and had no effect on tree growth at the pasture site. The total amount of fertilizer N recovered by the hybrid poplar trees ranged from 1-3% at the Alfalfa site and 3-5% at the pasture site. The second study involved planting four clones of hybrid poplar (Hill, Katepwa, Walker and WP-69) at the same two sites and applying fertilizer at rates of 0, 150 and 300 kg N ha^{-1} for first two years. Following the second growing season, Katepwa and WP-69 clones had the highest tree volumes of 750 and 1147 cm^3 of the four clones. Results from this study suggest that rooted stock types increase the successful establishment of hybrid poplar plantations. However, application of N fertilizer may not increase growth of trees if soil N is adequate. Other soil nutrients need to be measured prior to fertilization to determine what nutrients may be limiting for plant growth.

Gul *et al* (2006) conducted study to see whether the growth of *Araucaria heterophylla* seedlings could be hastened with the use of different gibberellic acid concentrations and nitrogen levels. The gibberellic acid (GA) concentrations used were 0ppm (control), 100 ppm, 200 ppm and 300 ppm, while nitrogen (N) levels were 0g N pot^{-1} (control), 1.0g N pot^{-1} and 2.0g N pot^{-1}. The effect both the GA and N was substantial for all the growth parameters studied. Maximum plant height (42.4 cm), stem thickness (1.43 cm), lateral branch length (22.7 cm), internode length (8.6 cm), root length (30.9 cm), root thickness (1.18 cm), number of roots (15.3) and plant survival (97.8%) were observed in plants treated with 300 ppm GA, while minimum values for all the mentioned parameters were recorded in control. In case of nitrogen dose, maximum plant height (36.1 cm), stem thickness (1.05 cm), lateral branch length (19.4 cm), internode length (6.2 cm), root length (25.5 cm), root thickness (0.89 cm), number of roots (11.8) and plant survival (98.3%) were observed for plants supplied with 2.0g N per plant, while the minimum for all the above parameters were found in control. The interaction between different gibberellic acid concentrations and nitrogen levels was non-significant in case of all the studied parameters.

Fillion *et al* (2009) evaluated that when an equivalent of 120 kg No_3-N, 40 kg P_20_5-P and 85 kg K_20-k per hectare per year is applied by means of irrigation with waste water, no mortality occurred and stem biomass production of both poplar and willow are not statistically different on irrigated and control area. However, *S.viminalis* revealed to be more tolerant in flooded condition since these corresponded more closely to its nutritional requirement (foliar concentration of 20 mg-N per gram).

Martin and Nils-Erik (2005) evaluated the suitability of pot experiments for predicting field performance, measured as shoot biomass production, by investigating determinants of growth in hybrid willows (*Salix* spp.) grown under various environmental conditions in the field, and by comparing the data with the results from a corresponding pot study. Biomass production in six hybrid willow clones, bred for use as bio-fuels, was assessed in three field trials located in central and south-eastern Sweden throughout the first 3-year cutting cycle. The determinants of biomass productivity, measured as biomass allocation and nitrogen (N) economy, were identified in one of the field trials. Key traits for shoot biomass production in the field were total leaf area and total amount of N; plant N losses by shed leaves were only partly controlled by leaf-litter N concentration. These key traits were also obtained from the pot study and related to shoot biomass production and abscission-leaf N loss in the field. Total leaf area and total N pool of plants grown in pot experiments were good predictors of long-term biomass production in the field, whereas shoot biomass production, specific leaf area and tissue N concentration of pot-grown plants were less suitable as predictors of field performance. Relationships between the key traits and shoot biomass production were clone-specific, indicating the need for analysis of growth traits at the clone level if field performance of trees is to be evaluated based on data from pot studies. Nutrient loss components are important for tree performance in the long term and evaluations of nutrient loss characteristics at the individual-tree level should focus on nutrient pools lost rather than on nutrient concentrations in abscised plant parts.

Martin Weih (2009) examined six commercial willow (*Salix* spp.) varieties to investigate the effects of genotype and environment on spring and autumn phenology and the relationships between phenology, shoot growth and leaf nitrogen (N) retranslocation. The willows were field grown under different irrigation and fertilization in central Sweden. Two independent data sets of bud-burst, leaf unfolding duration, growth cessation and the timing of leaf abscission were assessed, and the biomass and leaf N data from the end of the first cutting cycle were used. Bud-burst date varied by 19 and 39 days in the 2 years and leaf unfolding duration varied by 13 and 38 days. Growth cessation varied by 2.5 weeks and completion of leaf abscission (> 90% of leaves shed) by more than 3 weeks between the genotypes and treatments. Bud-burst date was inversely correlated with leaf unfolding duration (R^2 = 0.96). Significant effects of the duration of leafy period (bud-burst to leaf abscission) and bud-burst date on shoot growth were found. Delayed growth cessation and leaf abscission were generally associated with a greater biomass production, but especially the relationship between growth cessation and biomass was weak. The results show that the timing of bud-burst and leaf abscission is more important for willow biomass production than growth cessation. Delayed leaf abscission has a negative effect on leaf N retranslocation and increases the N losses.

Mariusz *et al* (2011) studied the biomass yield and morphological traits of plants in an experiment involving six genotypes of willow in northern Poland. Willow was planted using a pole cutting system on sites that were unsuitable for food crops. The results from the first rotation of a four-year cutting cycle. In the field trial, the average willow biomass yield of oven-dry matter was 7.87 Mg ha^{-1} $year^{-1}$. Willow plants that were planted as pole cuttings after four growing seasons reached a height of 6.64 m and a stem diameter of 50.5 mm. Clone UWM 043 produced higher yields and more favourable morphological traits when compared to registered Polish cultivars. The willow biomass yield obtained on peaty muck soil was significantly higher than from willow that was grown on heavy textured silt soil. The biomass harvested from plots planted at a density of 5,200 plants ha^{-1} was 14% lower than plots that had a density of 7,400 plants ha^{-1}.

Chauhan *et al* (2002) studied that nitrogen level 150 kg per ha produced maximum response in leaf moisture content, moisture retention capacity leaf N, K and total soluble protein followed by 100, 50 and 0 kg per ha levels. Leaf sugar content had an inverse relationship in mulberry with the applied N levels. Between clones' Punjab local was comparatively better in all the leaf quality characters except leaf P content. Polynomial equation of second degree were fitted to predict the maximum responsive nitrogen level.

Khamis *et al* (2013) examined the effects of mineral nitrogen (N) and phosphorus (P) and their combination (N+P) as well as biofertilizers namely phosphorene and nitrobin on vegetative growth, biomass, content and uptake of N, P and K in leaves of *Melia azedarach* and *Populus euphratica* seedlings. Five fertilizer treatments in addition to no fertilized seedlings used as control were laid out in a complete randomized design with three replicates. The result clearly showed that growth response of both species in terms of height, stem diameter, leaves fresh weight, leaves dry weight, stem fresh weight, stem dry weight as well as NPK content/uptake in leaves increased by the proposed fertilization treatments compared with control. However, the growth response may vary according to treatment and species used. Nevertheless, N+P application enhanced the growth efficiency of *Melia azedarach* through increasing the vegetative growth, biomass and content and total uptake of N, P and K in leaves, whereas, phosphorene was the least among the fertilizer sources, except for height and P content in leaves, which were increased progressively. In case of *Populus euphratica*, N and N+P were the highest for increasing the growth and biomass as well as content/total uptake of foliar N, P and K. Similarly, heights and N content in leaves responded considerably by phosphorene. Moreover, seedlings of both species responded more for mineral N, P, or N+P than biofertilizers, suggesting that the poor status of the soils used could be the cause. The overall results suggest that the response of seedling species to fertilization will vary depending on soil properties and the species used. Under the condition of this study, N and N+P fertilization are recommended in *Populus euphratica* and *Melia azedarach* plantation. Agro and Zheng (2014) reported 2.5 kg m^{-3} N controlled released fertilizer in *Salix.*

CHAPTER-III

MATERIALS AND METHODS

The present study entitled "Effect of cutting size and nitrogen fertilizer on nursery stock of *Salix alba*" was conducted in 2015-16 on nursery area of Department of Forestry and Natural Resources, PAU. Details about the collection of material, experimental sites, experimental procedures and methodology adopted are described in this chapter as follows:

3.1 Collection of cuttings

700 Cuttings were collected from University Seed Farm, Ladhowal, Ludhiana of two size i.e. 0.50-1.50. cm and 1.51 to 2.50 cm. Cutting were raised during the month of February, 2016.

3.2 Experimental site

The study was carried out in the teaching area nursery of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana. The study area is at 247m above mean sea level and lies at 30°45' N latitude and 75°40' longitude, represents central zone of Punjab. Climate is sub-tropical to tropical with a long dry season from late September to early June and wet from July to early September. May and June are the hottest months where, December and January are the coldest. Frost occurrence is not common. On an average site receives 704 mm rainfall, which is not evenly distributed and most of it (i.e. 75-80% is received during July-September. Meteorological data during the study period is given in Table 1 .

3.3 Experimental design

The experiment was laid out in Randomized Block Design. The other details of the trial are as under:

Number of Treatments	: 10
Cutting size	: 2
Nitrogen dose	: 5
No. of replications	: 3
Experimental design	: Randomized Block Design (Factorial)

Treatment details

a) Cutting size (2)

0.5-1.50cm

1.51-2.50 cm

Table 1: Meteorological data during the study period 2015-16

SMW	Air temperature (^oC)			Relative humidity (%)		Mean	Wind velocity (m/sec)	Sunshine hours	Rainfall (mm)	Evaporation (mm)
	Max	Min	Mean	Evening	Morning					
6	21.4	8.2	14.8	88.6	48.3	68.4	3.9	6.6	0.1	2.5
7	22.1	7.5	14.8	89	41	65.4	2.7	7.8	0.1	2.4
8	24.2	11.8	18.0	93.9	53	73.4	3.8	8.0	1.1	2.7
9	28.0	12.6	20.3	93.9	42.0	67.9	1.4	7.8	0.0	2.9
10	27.3	14.0	20.6	90.9	44.4	67.6	3.2	9.1	1.2	3.5
11	23.8	14.8	19.3	90.7	57.7	74.2	4.9	5.0	3.7	3.3
12	29.6	14.1	21.9	84.6	36.1	60.4	4.0	9.3	0.9	4.1
13	31.2	15.9	23.5	84.6	34.9	59.7	3.5	9.4	0.0	5.6
14	34.1	20.1	27.1	74.3	31.6	52.9	3.9	5.7	0.0	5.8
15	38.6	18.2	28.4	71.0	12.0	41.5	2.3	8.2	0.0	8.0
16	39.1	21.6	30.4	59.6	18.6	39.1	3.9	10.0	0.4	9.1
17	37.6	18.6	28.1	54.3	15.1	34.7	3.2	11.9	0.0	9.8

b) Nitrogen doses (5) (kg N/ha in 3 split doses – 15 days, 1.5 months and 2.5 months after raising cutting)

Nil (control) 0 kg N/ha

50 kg N/ha

100 kg N/ha

150 kg N/ha

200 kg N/ha

Cuttings were raised in polythene bags of 10 x 20 cm size and cutting were irrigated regularly. Soil from polybags was analysed initially and details are given in table 2.

Table 2: Physio-chemical characteristics of the soil

Characteristics	**Contents**
pH (1:2)*	8.2
Organic carbon (%)	0.27
Mechanical composition	
Sand (%)	71.2
Silt (%)	18.0
Clay (%)	11.80
Texture	Loamy sand
Available N	177
Available P	15.2
Available K	209

*(1:2, Soil: water suspension)

3.4 Observations recorded

Observations for plant height, collar diameter, number of branches, shoot biomass (gm), root biomass and stock vigour index were recorded after six months from the date of planting.

3.4.1 Plant height (m)

The height of the main shoot was recorded from the ground level to the apex of the leading shoot by using measuring scale.

3.4.2 Collar diameter (cm)

Collar diameter of the plant was measured with the help of digital calliper at the collar region i.e. 2cm above the soil surface.

3.4.3 Number of branches per plant

For these Primary branches of plants having diameter above 5 mm were recorded

Plate 1 : Nursery Experiment of *Salix*

from three plant randomely from each treatment and replication.

3.4.4 Shoot biomass (gm)

Two plants from each replication per treatment were selected randomly and uprooted. The shoot portion was separated from the root and it was weighed on an electronic balance to get fresh shoot weight. The shoots were dried in hot air oven at 70 ± 2^{o}C and weighed to get dry shoot weight.

3.4.5 Root biomass (gm)

The root portion without soil, which was separated from shoot, was weighed on a electronic balance to get fresh root weight. The roots were dried in hot air oven at 70 ± 2^{o}C and weighed to get dry shoot weight.

3.4.6 Stock vigor index

The stock vigor index was calculated by using formula:

= Survival% X Plant height

3.4.7 Sturdiness quotient

The sturdiness quotient was calculated by using formula:

= Plant height (cm) / Collar diameter (cm)

3.4.7 N, P and K in plant

- Available nitrogen was determined by alkaline permanganate method as modified by Subbiah and Asija (1956).
- Available phosphorus was extracted in 0.5M NaHCO3 adjusted to pH 8.5 (Olsen *et al* 1954) and phosphorus was determined by phospho-molybdate blue colour method (Jackson1973).
- Available potassium was extracted with neutral ammonium acetate and potassium in the extract was determined by flame photometer as described by Jackson (1973).

3.5 Statistical analysis

The statistical analysis of the data was done using a factorial randomized complete block design and least significant differences (LSD) were computed at the 5 per cent probability level (Gomez and Gomez 1984). The statistical analysis was carried out with the help of CPCS-1 software and the results so obtained are discussed accordingly

3.5.1 Mean: The mean value of each parameter was worked out by dividing the sum by corresponding number of observations:

$$\bar{X} = \sum \frac{Xij}{N}$$

Where, Xij = Any observation in ith treatment and jth replication

$\bar{X}$ = Mean of character X

N = Total number of observations

3.5.2 Anova

Randomized block design

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F_{cal}
N level (t)	t-1	tss	mst	mst/mse
Cutting size	c-1	css	msc	msc/mse
Error	(t-1)(c-1)	ess	mse	
Total	n-1	tss	mst	

3.5.3 Critical difference (CD)

In order to compare the mean of various parameters, the critical difference (CD) was calculated (at 5 per cent level of significance) by formula:

$$CD = S.Ed \times t_{0.05}$$

Here S.E. is the standard error of the difference of the treatment means to be compared and is equal to:

$$SE_d = \sqrt{2MSe/R}$$

With MSe as error means sum of square and R as number of replications and 't' is the tabulated value of 't' at 5 per cent or 1 per cent level of significance for the degree of freedom of error mean square.

3.5.4 Calculation of correlation coefficient

It is the numerical measure of the linear relationship between two variables. The value of coefficient of correlation was tested for significance of relationship. (Panse and Sukhattme 1967).

$$r = \frac{n\left(\sum xy - \sum x \sum y\right)}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

Where;

r = Coefficient of correlation

x,y = Variables

N = Number of observation

$\sum$ = Summation

For testing simple correlation,

$$T = \frac{r}{\sqrt{(1-r)^2}} \times \sqrt{(n-2)}$$

r = Simple correlation

n = Number of coefficients in the sample

3.5.5 Anova

Source of variation	Degree of freedom
Block	2
Nitrogen	4
Cutting size	1
interaction	4
Error	18
Total	29

CHAPTER-IV

RESULTS AND DISCUSSION

This chapter highlights the result of the studies undertaken to evaluate the growth performance of *Salix* with respect to cutting diameter size and different N levels. The relevant data has been presented in tables and appendices and result discussed in the light of available literature.

Results obtained in the study are discussed in two principal headings.

4.1 Growth performance in response to cutting size and nitrogen fertilization

4.2 Impact of nitrogen doses on vigor

4.1 Growth performance in response to cutting size and nitrogen fertilization

The growth and biomass parameters viz., plant height, collar diameter, number of branches showed highly significant difference between the cutting sizes and in different N levels.

Table 3: Effect of cutting size and nitrogen fertilization on growth performance

Cutting size	Plant height (cm)	Collar diameter(cm)	No. of branches/ plant
0.50-1.50cm	1.04	0.52	2.59
1.51-2.50 cm	1.59	0.82	3.33
LSD(p=0.05)	0.13	0.06	0.30
Nitrogen level (kg/ha)			
0	0.94	0.43	0.75
50	1.12	0.52	1.83
100	1.25	0.67	3.42
150	1.56	0.86	4.25
200	1.69	0.88	4.55
LSD(p=0.05)	0.21	0.10	0.48

4.1.1 Plant height

Data depicted in table no. 3 revealed that the two cutting sizes differs significantly in plant height. Average plant height increases from 1.04 cm to 1.59 cm for lower to higher cutting size. Significant increase in plant height was observed when 150 kg N/ha was applied and further increase in nitrogen dose increased plant height but non-significantly (Figure 1, Figure 2). The increase in plant height with nitrogen application may be attributed to the role of nitrogen in development and differentiation of tissue and cell division, which helped to increase the plant height. The increase in plant height with increase in cutting diameter was also recorded by Saini *et al* (2002) in *Salix*. Fast growing plants has higher requirement of nutrient, which is evident from results that plant height increased with increase in N dose.

Figure 1: Effect of cutting size and nitrogen fertilization on plant height.

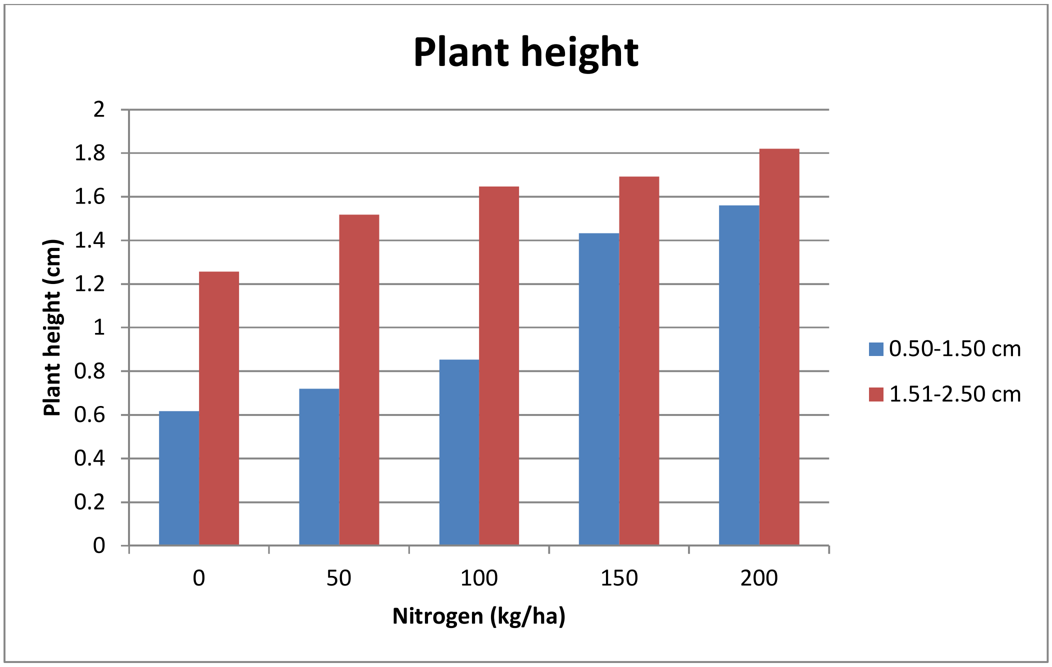
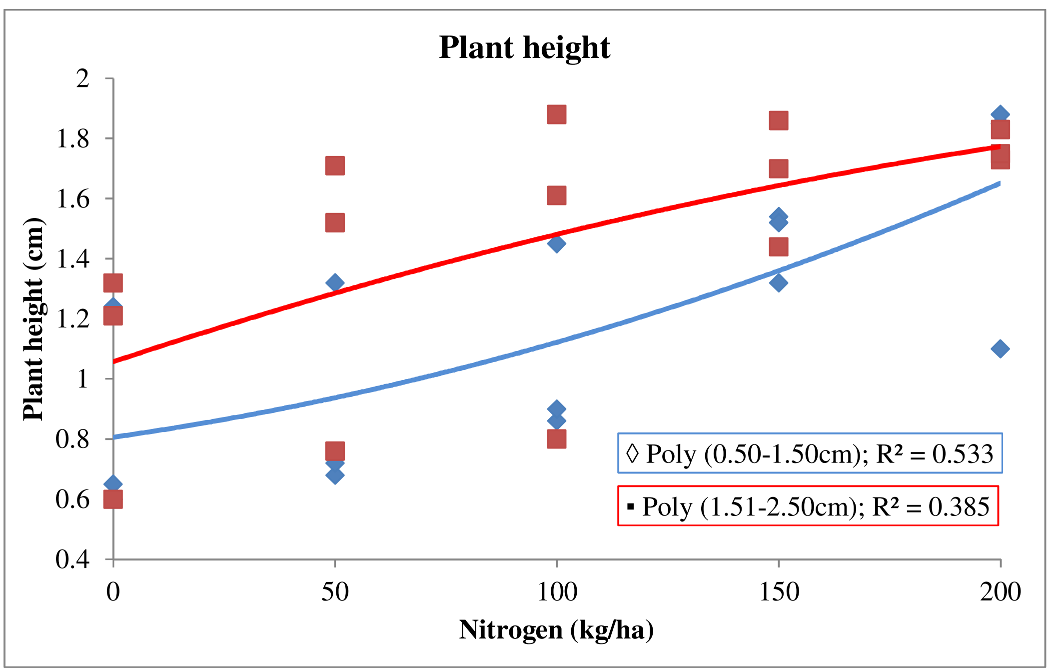


Figure 2: Correlation of cutting size and nitrogen fertilization on plant height.



4.1.2 Collar diameter

Collar diameter differs significantly when two cutting sizes were compared to each other. Average collar diameter increases from 0.52cm to 0.82 cm when cutting size of 0.50-1.50 cm and 1.51-2.50 cm were grown, respectively (Table 3). In case of nitrogen level, maximum collar diameter of 0.88 was recorded with the application of 200 kg nitrogen/hectare, while minimum (0.43) was recorded in control. Dose of 150 and 200 kg N/ hectare differs non-significantly (Figure 3, 4). Chmelar (1973) reported that almost any size of cutting can be used in *Salix* but Mugal (1996) revealed maximum growth and survival in 1.1-1.5 cm diameter class and even higher cutting diameter had lower growth which was in contradiction to earlier study of Saini *et al* (2002). However, Kang *et al* (2015) recorded suitability of 1-1.50 cm cutting size for growth.

The application of different doses of nitrogen revealed a significant and quadratic effect on the growth characters viz., collar diameter. The mean values of each of these characters increased with increasing N level upto 150 kg N/ha. The subsequent increase in nitrogen beyond this level, however, made positive but non-significant effect. It may further be seen that for all these characters, the N treated plants attained higher values as compared to untreated plants. Malik (1987) and Koul (1989) have also reported the increase in nitrogen content with increase in N fertilization in *Eucalyptus tereticornis* and *Bauhixia variegali,* respectively; Purshottam (1993) and Kumar (1993) in *Ulmus laevigata* observed that application of nitrogen upto 80 kg/ha had a positive response at higher doses of N. As it is quite obvious that the dose of fertilizer for a particular species depends upon the initial fertility status of soil, therefore, the medium status of nitrogen in the soil which supplemented upto 150 kg N per ha could have been sufficient to meet the nitrogen requirement of the seedlings.

4.1.3 Number of branches/ plant

Number of branches of three randomly selected plants from each plot were counted and their average was calculated. It was observed that mean number of branches per plant followed an increasing trend with increasing application of nitrogen. In control, average number of branches per plant were 0.75, which enhanced to 1.83, 3.42, 4.25 and 4.55 when the rate of nitrogen application was raised to 50, 100, 150 and 200 kg N/ ha respectively (Table 3, Figure 5, 6). Number of branches also increased from 2.59 to 3.33 with increase in cutting size from 0.50-1.50 to 1.51-2.50.

Figure 3: Effect of cutting size and nitrogen fertilization on collar diameter.

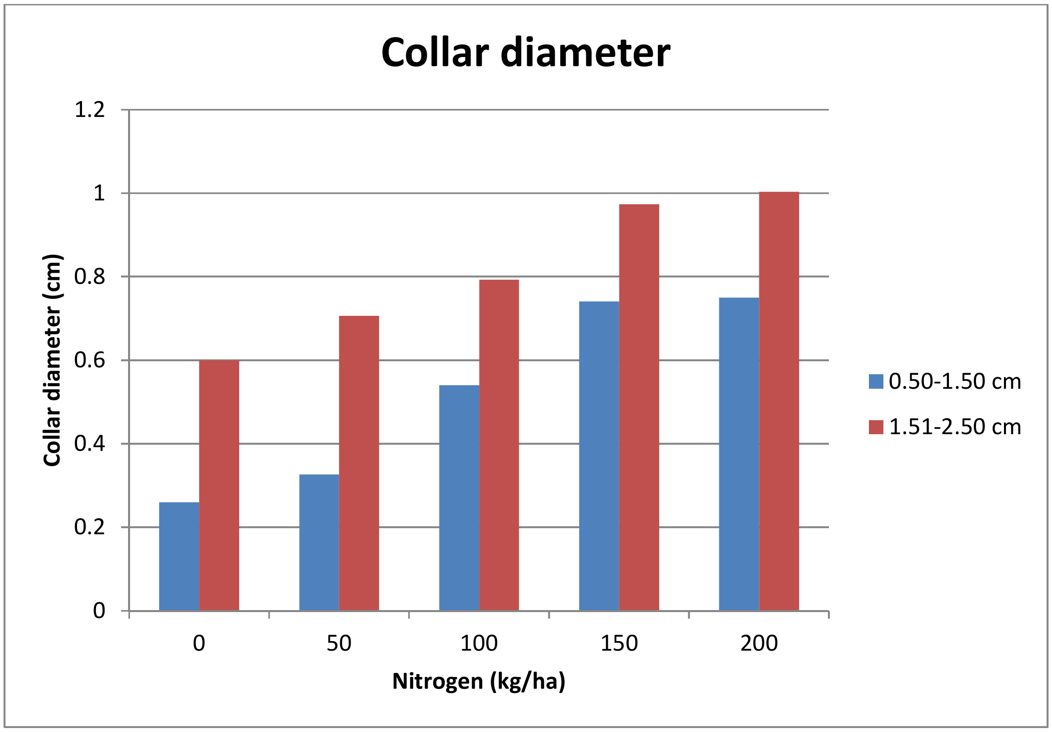


Figure 4: Correlation of cutting size and nitrogen fertilization on collar diameter.

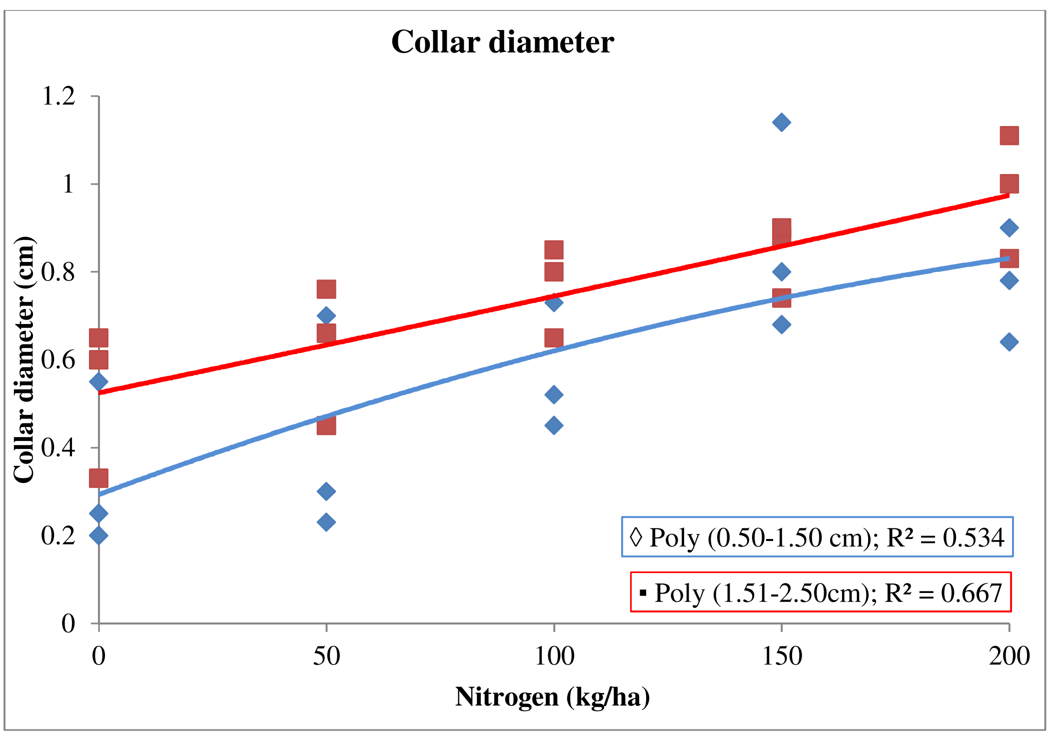


Figure 5: Effect of cutting size and nitrogen fertilization on number of branches/ plant.

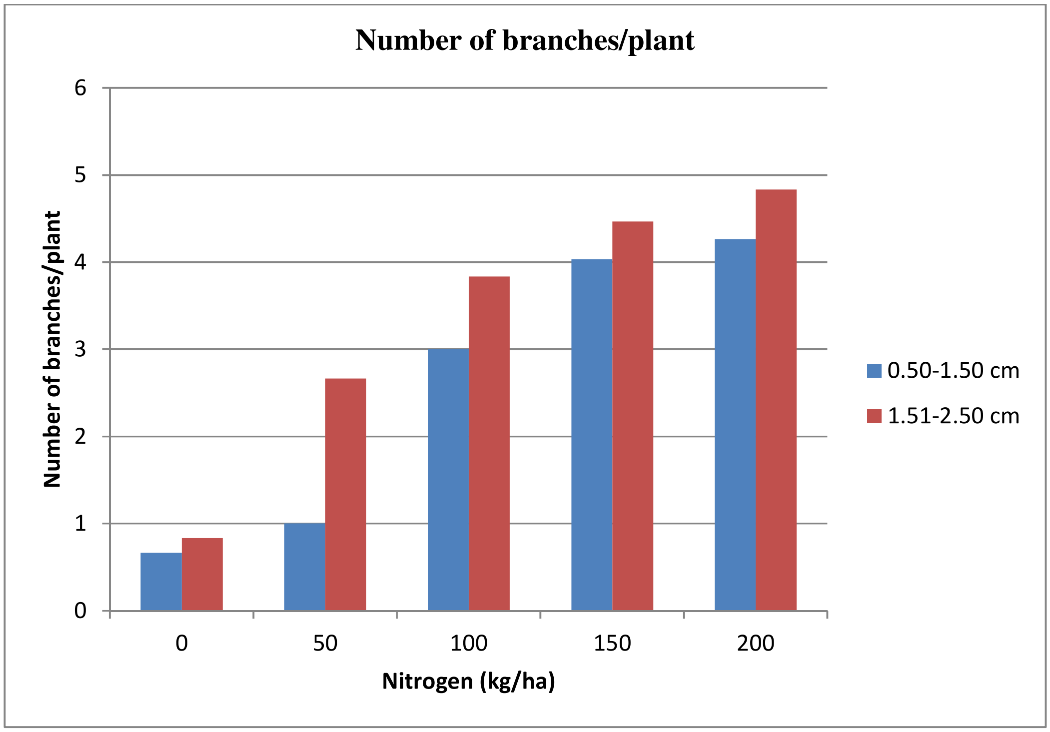
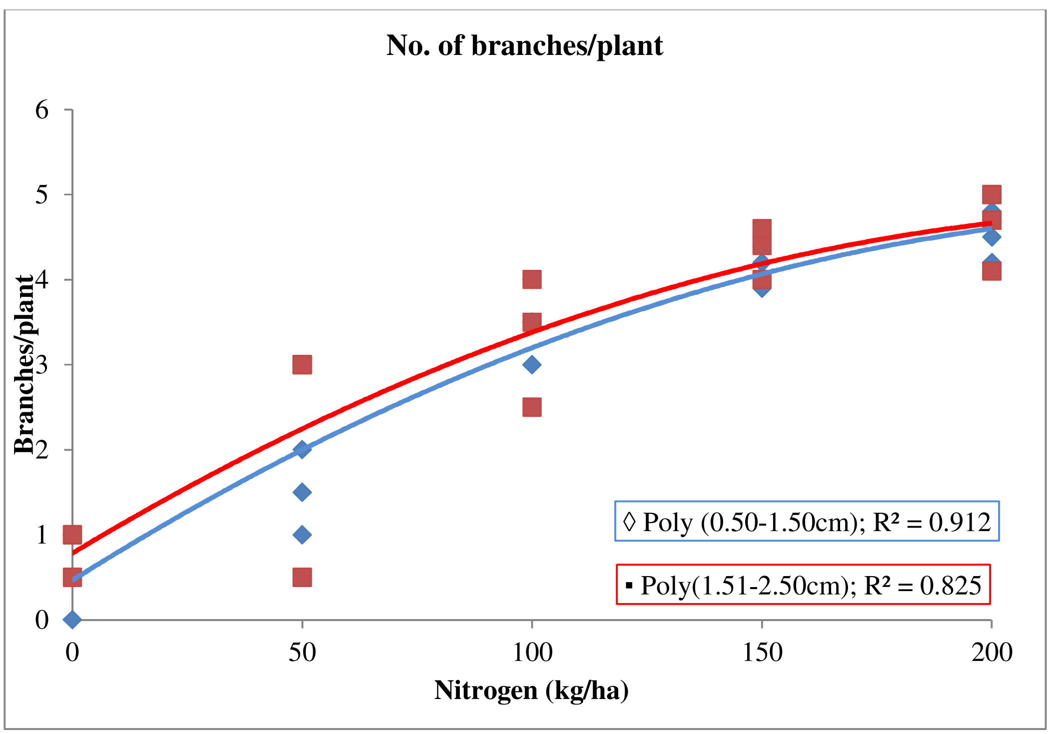


Figure 6: Correlation of cutting size and nitrogen fertilization on number of branches/ plant.



4.2 Biomass

All the biomass parameters viz., fresh and dry shoot, root and total biomass varied significantly between two cutting sizes and among five nitrogen levels. Data pertaining to variation in these parameters are presented in table 4.

Table 4: Effect of cutting size and nitrogen fertilization on biomass parameters

Cutting size	Dry shoot biomass (gm)	Dry root biomass (gm)	Total biomass (gm)
0.50-1.50 cm	31.14	10.47	41.61
1.51-2.50 cm	47.13	13.17	89.74
LSD(p=0.05)	1.50	0.53	2.40
Nitrogen level (kg/ha)			
0.00	24.96	4.99	49.32
50	31.53	7.83	59.85
100	39.18	11.99	71.58
150	48.93	16.79	84.97
200	51.08	17.51	88.46
LSD(p=0.05)	2.36	0.84	3.80

4.2.2 Dry shoot biomass

Dry shoot weight in cutting size of 1.51-2.50 cm was significantly more as compared to cutting size of 0.50-1.51 cm. The mean dry shoot weight was found to be 47.13 gm in cutting size of 1.51-2.50 cm and 31.14 gm in cutting size 0.50-1.50 cm (Table 4). Data further revealed that the dry shoot biomass differs significantly for increasing level of nitrogen as compared to control. Nitrogen applied @ 200 kg/hectare recorded maximum dry shoot biomass of 51.08 gm and dry shoot biomass for control was found to be 24.96 gm (Fig. 8 and 9). The nitrogen application of 150 and 200 kg/hectare did not differs significantly. Interaction between cutting size and nitrogen application for the dry shoot biomass showed significant variation (Table 5).

Table 5: Effect of cutting size and nitrogen fertilization interaction on biomass.

Treatment (kgN/ha)	Dry shoot biomass (gm)		Dry root biomass (gm)		Total biomass (gm)	
	0.50-1.50 cm	1.51-2.50 cm	0.50-1.50 cm	1.51-2.50 cm	0.50-1.50 cm	1.51-2.50 cm
0.00	11.10	38.83	2.23	7.76	20.92	77.73
50	22.26	40.79	6.68	8.98	41.21	78.48
100	28.60	49.77	10.02	13.95	51.04	92.13
150	45.40	52.46	15.76	17.81	70.85	99.09
200	48.36	53.79	17.68	17.34	102.15	101.29
LSD(p=0.05)	3.34		1.19		5.37	

Figure 7: Effect of cutting size and nitrogen fertilization on dry shoot biomass.

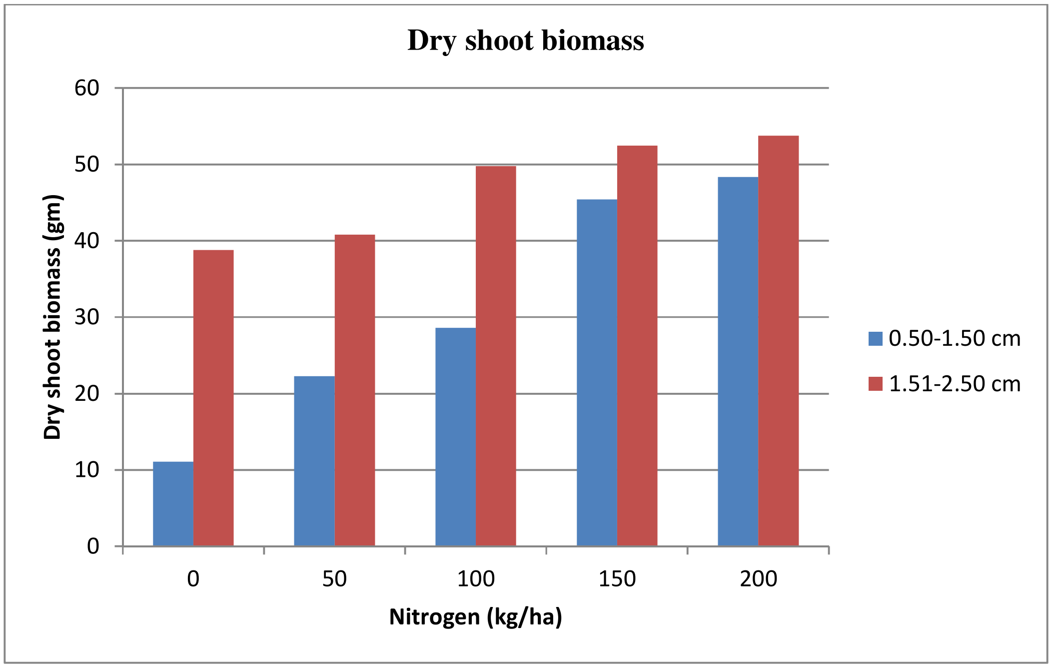
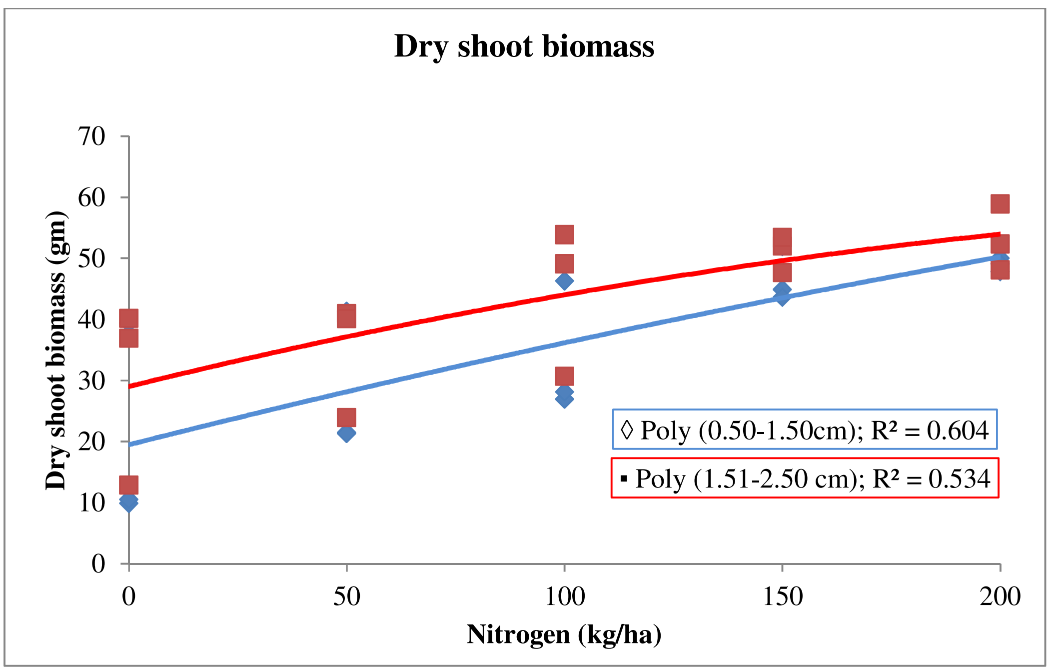


Figure 8: Correlation of cutting size and nitrogen fertilization on dry shoot biomass.



4.2.1 Dry root biomass

Dry root weight in cutting size of 1.51-2.50 cm differed significantly with cutting size 0.50-1.50 cm. The mean dry root weight was found to be 13.17 gm in cutting size of 1.51-2.50 cm and 10.47 gm in cutting size 0.50-1.50 cm (Table 4). Average dry root biomass increases from 4.99 to 17.51 gm when 200 kg N/ha was applied as compared to control respectively. Significant increase in dry root biomass was observed upto the application of 150 kgN/ha and non-significant increase was observed with further increase in nitrogen level i.e. 200 kg N/ha (Fig. 9 and 10).

Figure 9: Effect of cutting size and nitrogen fertilization on dry root biomass

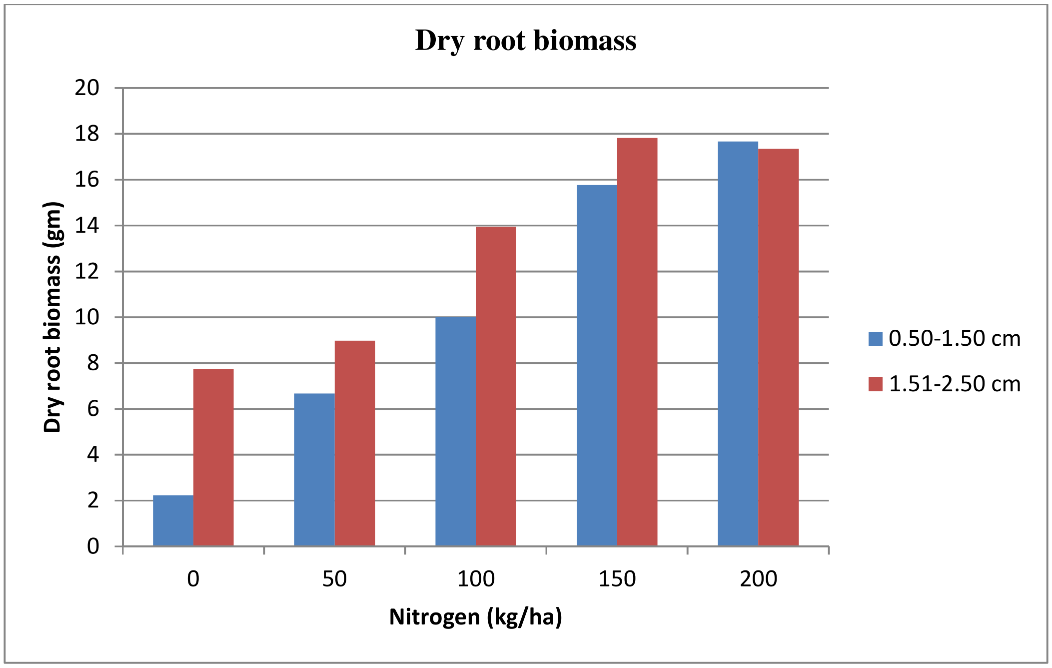
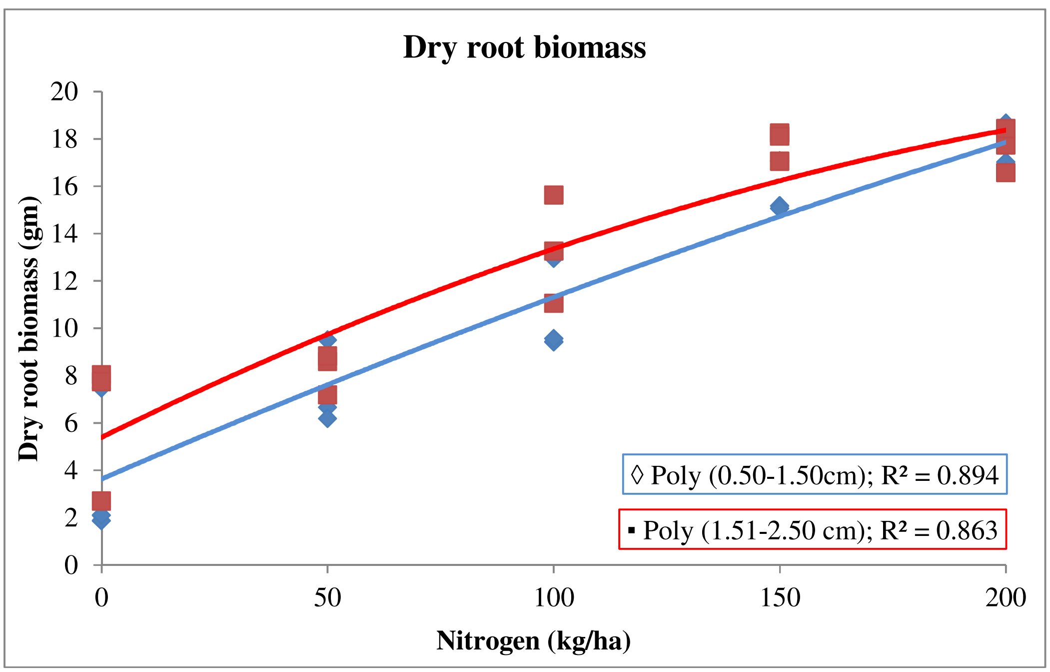


Figure 10: Correlation of cutting size and nitrogen fertilization on dry root biomass.



4.2.3 Total biomass

The data depicted in table no. 4 and 5 showed that total dry biomass varied significantly among the cutting size, which were found higher in 1.51-2.50 cm cutting size. The maximum was registered in 1.51-2.50 cm (89.74 gm), which was statistically lower with 0.50-1.50 cm (51.93 gm). Biomass is the most important parameters for selection of nursery stock. The nitrogen level of 200 kg/hectare recorded maximum total biomass of 88.46 gm and for control, it was found to be 49.32 gm. The total biomass with nitrogen dose of 150 and 200 kg/hectare does not differ significantly. Interaction between cutting size and nitrogen application for the total biomass showed significant increasing trend with increase in N level and cutting size. Toky *et al* (1996), Thakur *et al* (2003) and Chauhan *et al* (2012) also recorded enhanced growth and biomass in larger diameter cuttings. The different in growth and biomass due to cutting size may be referred to the reserved food material and C/N ratio. Deol and Khosla (1993) attributed to the increased growth with size of cutting to enhanced root and leaf area development of *Populus ciliate*.

Figure 11: Effect of cutting size and nitrogen fertilization on total biomass

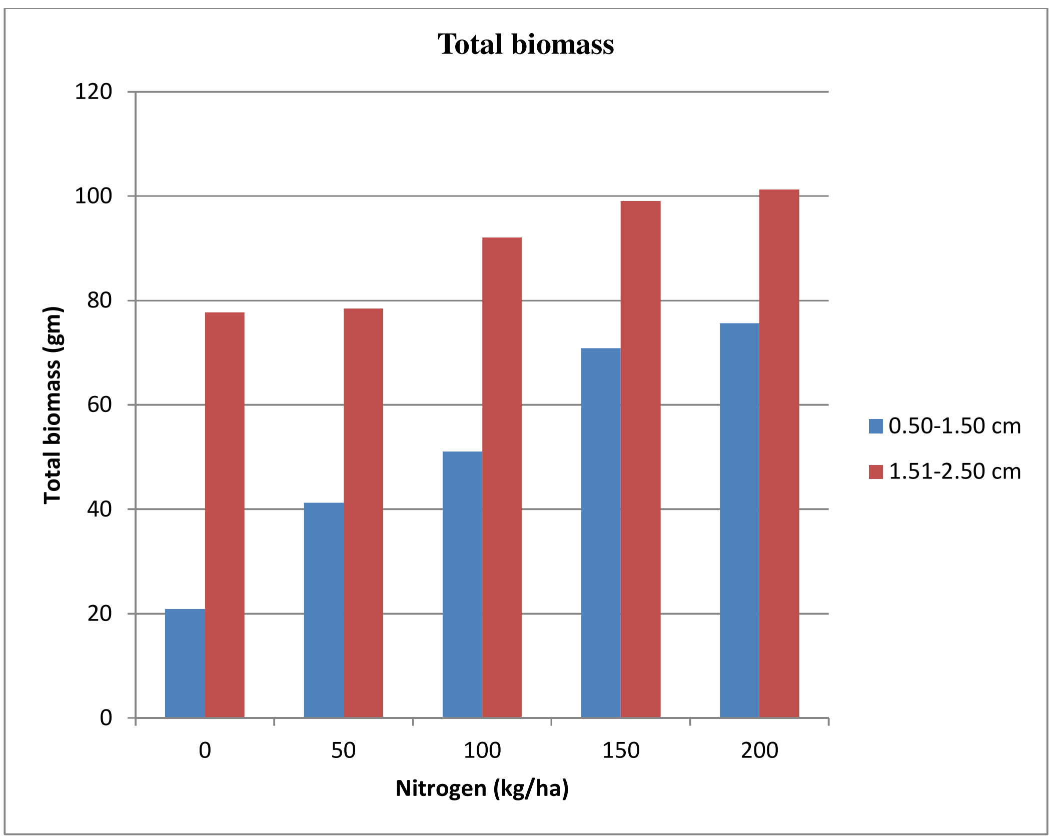
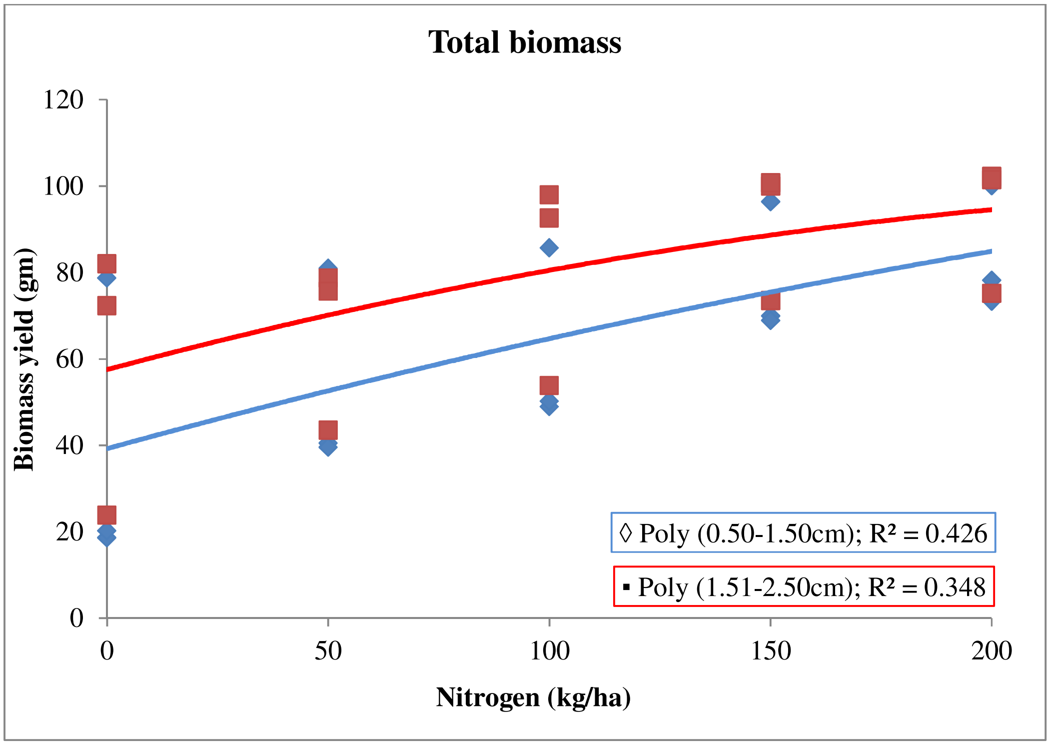


Figure 12: Correlation of cutting size and nitrogen fertilization on total biomass.



4.3.1 Nitrogen content

As shown in Table no.5 and 6 data revealed that the cutting size differed significantly for nitrogen content. The cutting size of 1.51-2.50 cm recorded 2.24 percentage of nitrogen which was significantly higher over 2.06 for cutting size of 0.50-1.50 cm. The results of the present study clearly indicate a variation in nitrogen content between cutting sizes. The dose of 200 kg nitrogen/hectare recorded maximum nitrogen content of 2.66 percentage, which did not differ significantly with the nitrogen dose of 150 kg/hectare. Interaction between cutting size and nitrogen application for nitrogen content showed a non-significant trend differences though followed increasing trend with increase in nitrogen level and cutting diameter. Similar findings have been observed in mulbury by Shivprakash *et al* (2000), Ali *et al* (1994) and Bajpai *et al* (2002). Van Dorsser and Rook (1972) found that applying N not only checks the loss of chlorophyll but also builds up N reserves especially in roots.

Table 5: Effect of cutting size and nitrogen fertilization on N P K contents in plants

Cutting size	Nitrogen Content (%)	Phosphorus Content (ppm)	Potassium Content (ppm)
0.50-1.50 cm	2.06	2299.53	6744.47
1.51-2.50 cm	2.24	2351.60	7201.53
LSD(p=0.05)	0.16	36.80	155.53
Nitrogen level (Kg/ha)			
0.00	1.39	2565.83	5618.17
50	1.93	2427.50	6541.17
100	2.22	2392.67	7077.33
150	2.55	2237.83	7635.67
200	2.66	2004.00	7992.67
LSD(p=0.05)	0.25	58.18	245.91

Table 6: Effect of cutting size and nitrogen fertilization on N P K contents in plants

Treatment (kgN/ha)	Nitrogen Content (%)		Phosphorus Content (ppm)		Potassium Content (ppm)	
	0.50-1.50 cm	1.51-2.50 cm	0.50-1.50 cm	1.51-2.50 cm	0.50-1.50 cm	1.51-2.50 cm
0.00	1.32	1.45	2531.67	2600.00	5641.67	5594.67
50	1.72	2.14	2464.67	2390.33	6139.00	6943.33
100	2.03	2.42	2407.00	2378.33	6914.33	7240.33
150	2.53	2.57	2166.33	2309.33	7175.67	8095.67
200	2.69	2.62	1928.00	2080.00	7851.67	8133.67
LSD(p=0.05)	NS		82.28		347.77	

Plate 2. Rooting response of different treatments in *Salix alba*

Figure 13: Effect of cutting size and nitrogen fertilization on nitrogen content

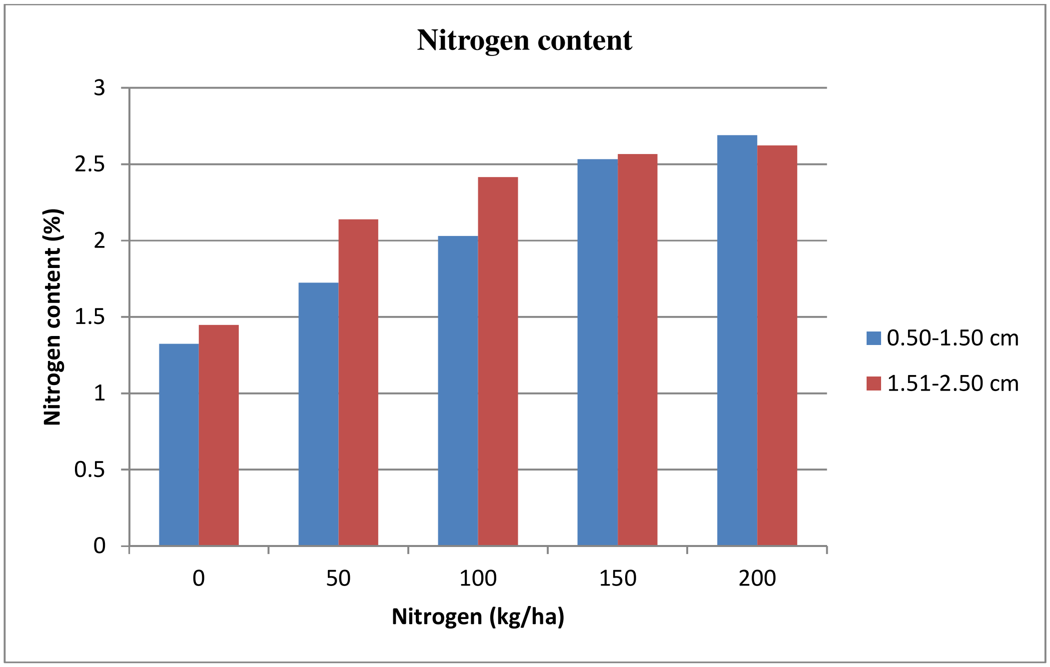
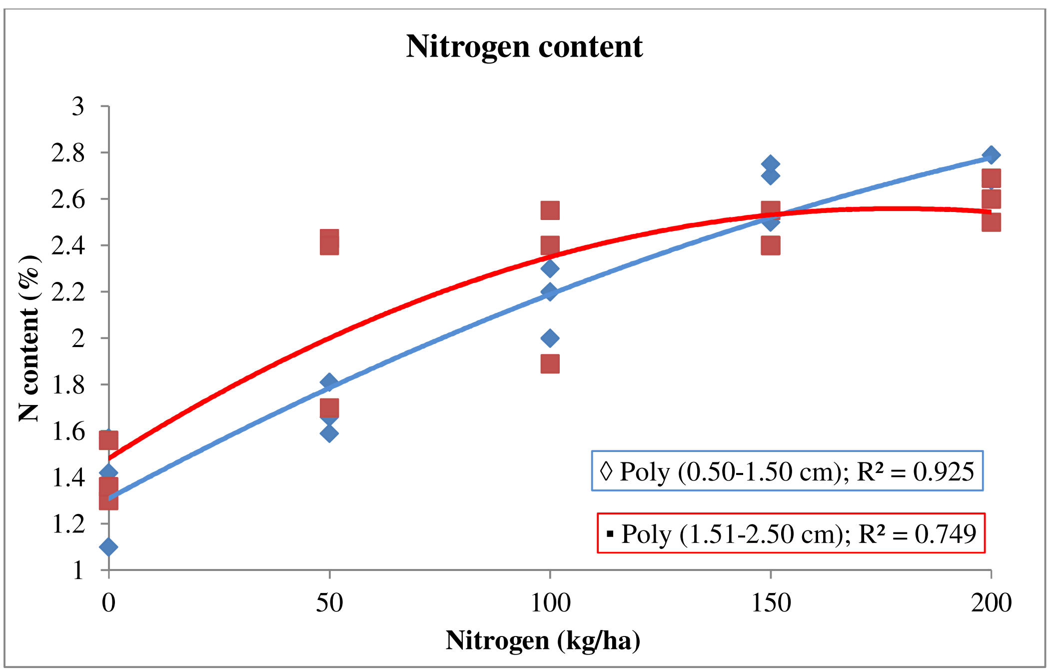


Figure 14: correlation of cutting size and nitrogen fertilization on nitrogen content



4.3.2 Phosphorus contents

The effect of increasing level of nitrogen on phosphorus uptake was found to be antagonistic. As the applied nitrogen increased from 0 kg N/ha to 200 kg N/ha the phosphorus content decreased from 2565.83 ppm to 2004 ppm. It was observed that there is 22% decrease in phosphorus uptake when 200 kg N/ha as compared to control. The phosphorus interaction between two cuttings was found to be significant. Figure 15,16 is the graphical and polynomial representation of the effect of cutting size and nitrogen fertilization on phosphorus content. The inverse relation of N and P can be explained by ionic competition, which directly or indirectly resulted from N fertilization and caused a reduction in P absorption. Similar trend was noticed by Sitailov and Lekhera (1974), Vanderboon and Pouwar (1960), Rao (1985) and Kumar (1993).

Figure 15: Effect of cutting size and nitrogen fertilization on phosphorus content.

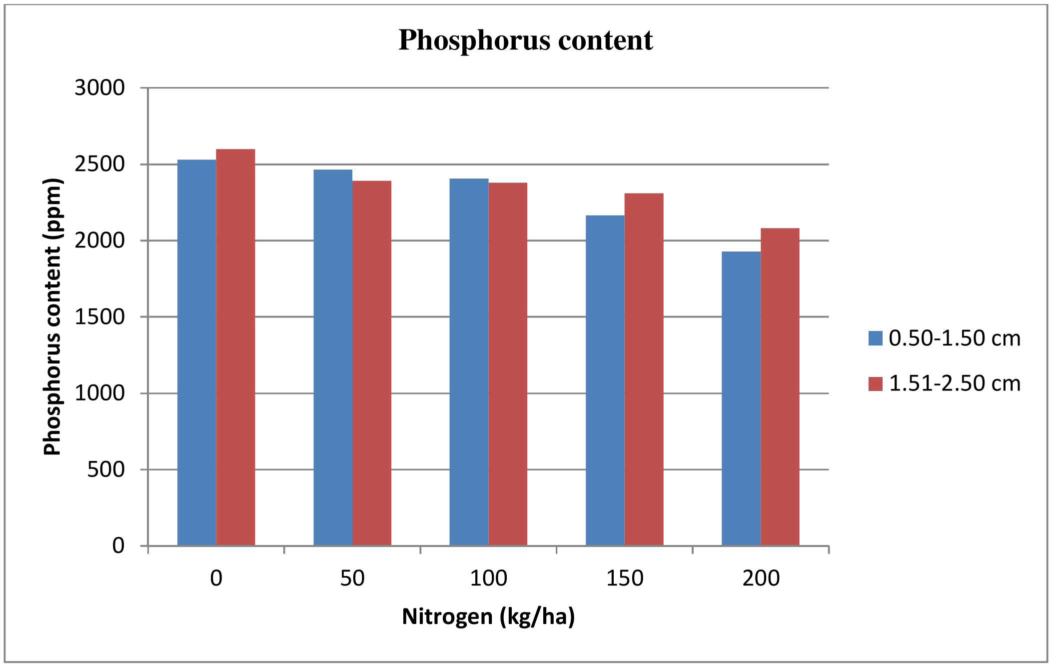
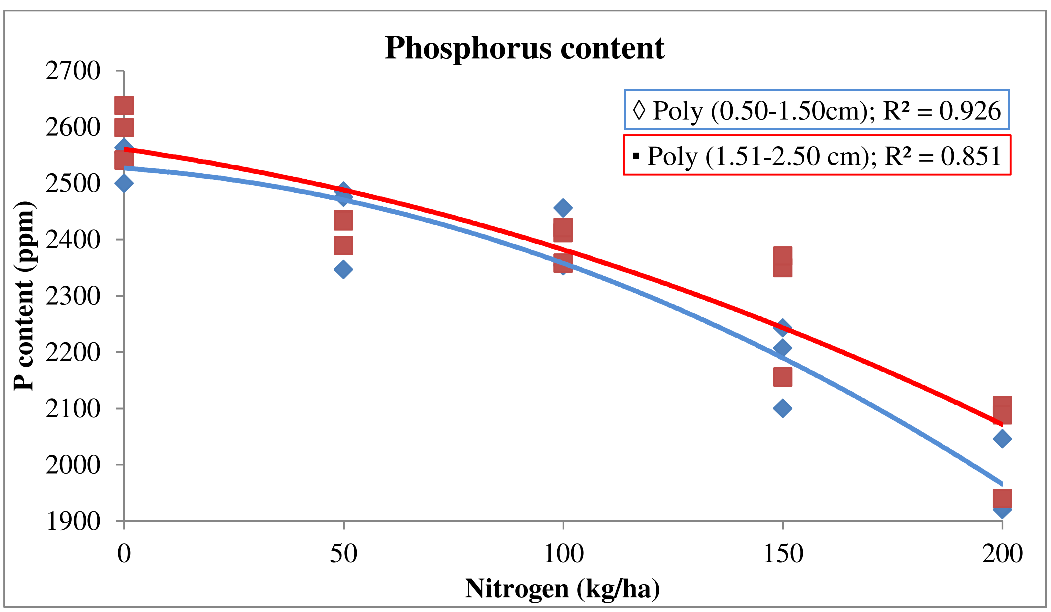


Figure 16: Correlation of cutting size and nitrogen fertilization on phosphorus content.



4.3. Potassium content

As represented in table 5 and 6, the potassium content increased significantly in 1.51-2.50cm cutting size as compared to 0.50-1.50 cm cutting size. Average potassium content increased from 5618.17 ppm to 7992.67 ppm when nitrogen dose of 200 kg N/ha as compared to control. But non significant increase in potassium content was observed when 200 kg N/ha was applied as compared to 150 kg N/ha. This trend show synergistic effect of nitrogen with potassium. Increase in soil nitrogen content increased the potassium uptake by plant. Ghosh *et al* (1997) and Bajpai *et al* (2002) had also recorded synergistic response of N and K.

Figure 17: Effect of cutting size and nitrogen fertilization on potassium content.

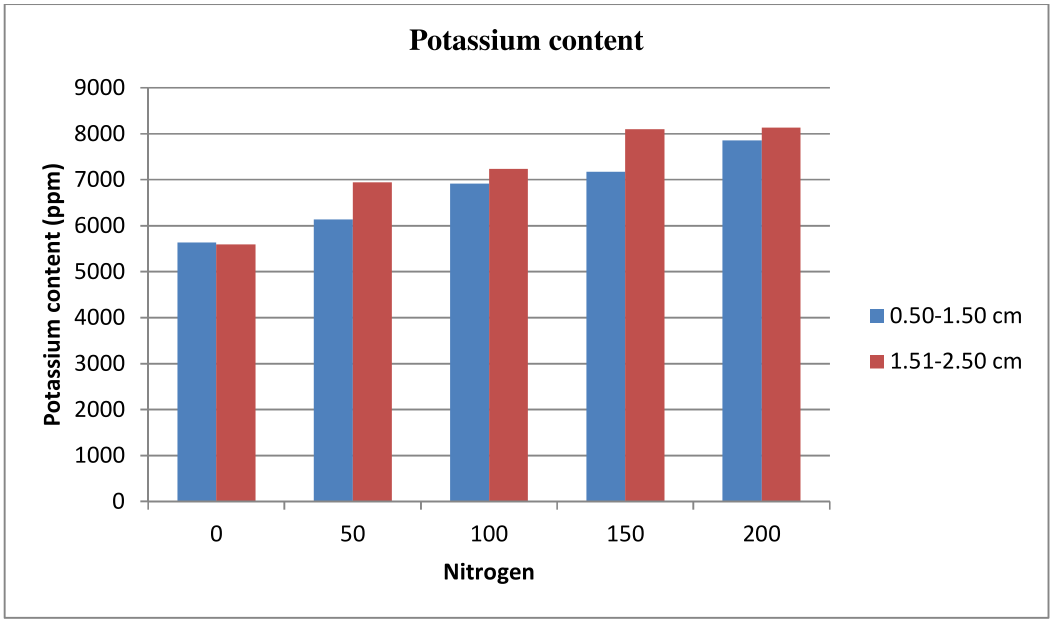
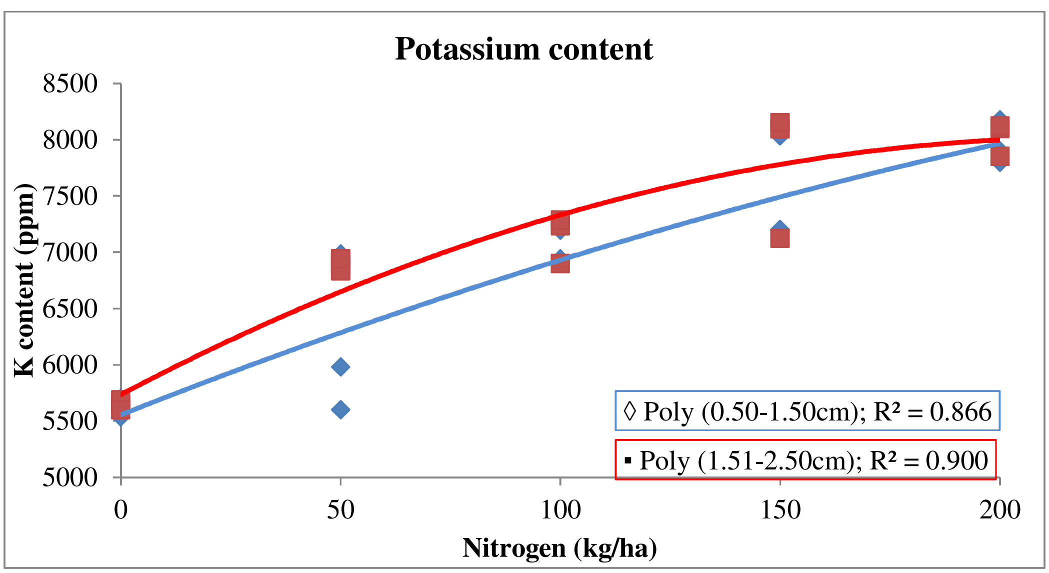


Figure 18: Correlation of cutting size and nitrogen fertilization on potassium content.



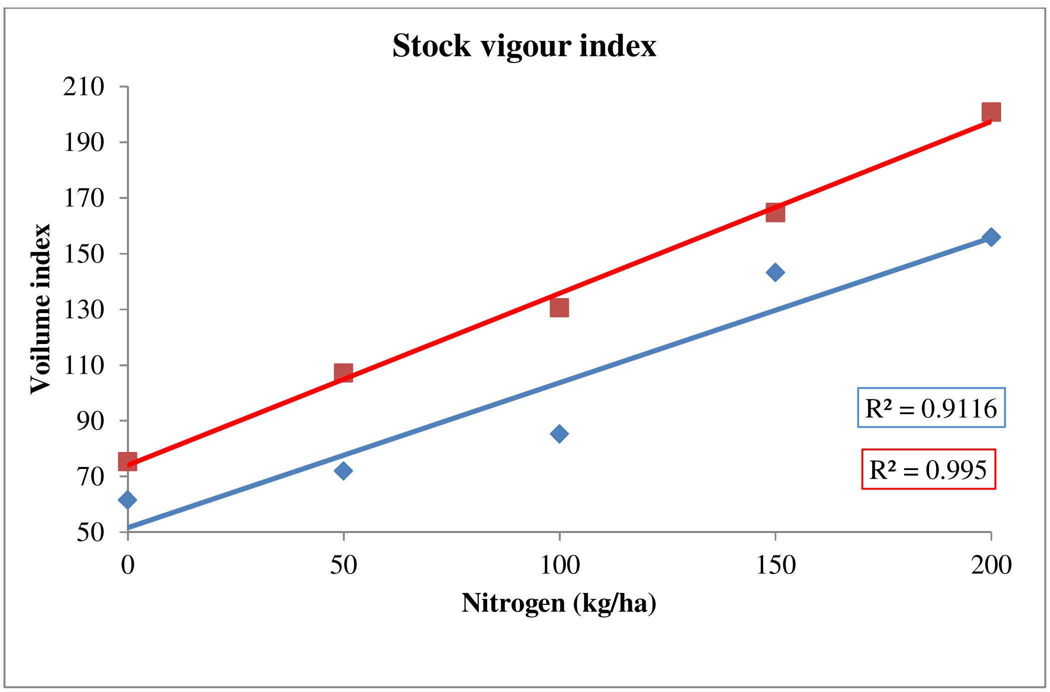
4.3.4 Stock vigour index

Liner relationship was obtained when Stock vigour index was regressed with increasing nitrogen level. Correlation coefficient of 0.995 was found with the linear curve of 1.51-2.50 cm cutting size, which was higher as compared to 0.911 in case of 0.50-1.50 cm scutting size. This is represented in figure 19.

Table 7: Effect of cutting size and nitrogen fertilization on Stock vigour index.

Treatment (kgN/ha)	Stock vigour index	
	0.50-1.50 cm	**1.51-2.50 cm**
0.00	61.67	75.40
50	72.00	107.18
100	85.33	130.63
150	143.33	164.81
200	156.00	200.80

Figure 19: Effect of cutting size and nitrogen fertilization on Stock vigour index.



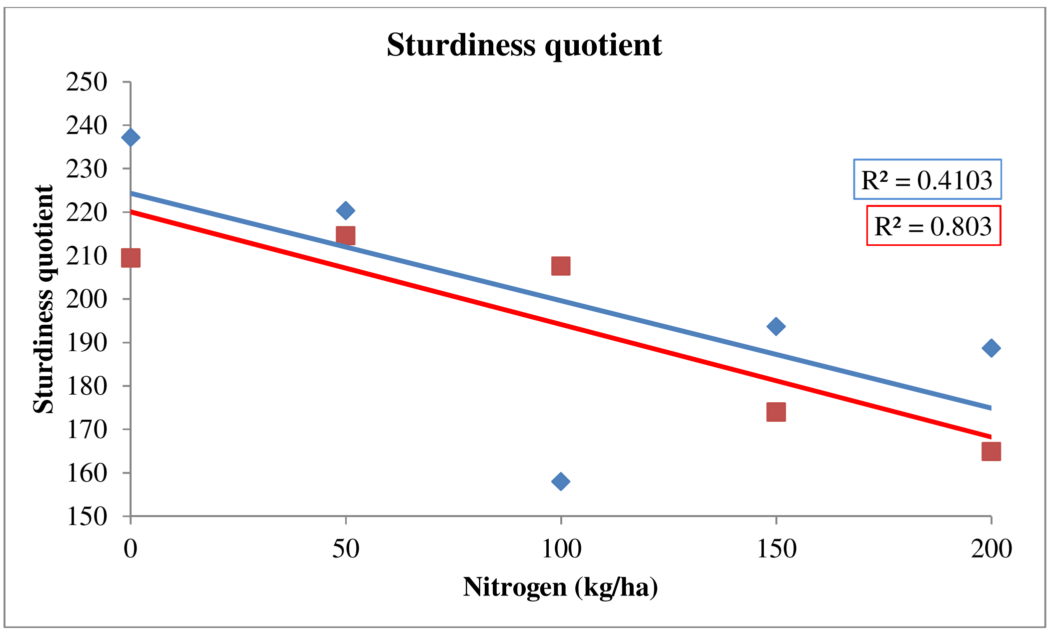
4.3.5 Sturdiness index

Sturdiness quotient decreases linearly as the nitrogen level increases from 0 kg N/ha to 200 kg N/ha. The decreases in sturdiness quotient was due to increase in collar diameter with increasing level of nitrogen. The sturdiness quotient was highly correlated in the cutting size of 1.51-2.50 cm (R^2=0.803) as compared to cutting size of 0.50-1.50 cm (R^2=0.410).

Table 8: Effect of cutting size and nitrogen fertilization on sturdiness index.

Treatment (kgN/ha)	Sturdiness index	
	0.50-1.50 cm	**1.51-2.50 cm**
0.00	237.19	209.45
50	220.39	214.62
100	158.02	207.58
150	193.69	173.98
200	188.70	164.96

Figure 20: Effect of cutting size and nitrogen fertilization on sturdiness index.



The shoot: root ratio also showed an increase in ratio, which is attributed to the more growth in shoot. With the application of Sutton (1969) stated that high fertility seems generally to reduce tree growth in favour of shoot growth. Russell (1977) also reported that improved N supply reduced size of root system relative to shoots of various species, although added nitrogen frequently increased root growth, but in reduced proportion to that of shoot.

4.3.6 Correlation of *Salix* growth parameters and NPK content

Simple correlation analysis was assessed between various growth parameters such as plant height, number of branches, collar diameter, root, shoot and total biomass with nitrogen, phosphorus and potassium content in *Salix*. The high and positive correlation suggested that with increase in level of nitrogen, there was increase in yield attributing characters of *Salix*. The Phosphorus uptake was negatively correlated with increasing level of nitrogen may be due to antagonistic effect.

Table 9: Correlation coefficients for different parameters

Pearson Correlation Coefficients, N = 30 Prob > |r| under H0: Rho=0									
	N	**P**	**K**	**PH**	**NB**	**CD**	**DSB**	**DRB**	**TB**
N N	1.00000	-0.80785 <.0001	0.90571 <.0001	0.76138 <.0001	0.92499 <.0001	0.78059 <.0001	0.79539 <.0001	0.88378 <.0001	0.70006 <.0001
P P	-0.80785 <.0001	1.00000	-0.79645 <.0001	-0.54198 0.0020	-0.78456 <.0001	-0.57448 0.0009	-0.60570 0.0004	-0.79299 <.0001	-0.43943 0.0151
K K	0.90571 <.0001	-0.79645 <.0001	1.00000	0.73523 <.0001	0.91742 <.0001	0.82593 <.0001	0.79222 <.0001	0.90660 <.0001	0.71868 <.0001
PH PH	0.76138 <.0001	-0.54198 0.0020	0.73523 <.0001	1.00000	0.74704 <.0001	0.84636 <.0001	0.91331 <.0001	0.81113 <.0001	0.90218 <.0001
NB NB	0.92499 <.0001	-0.78456 <.0001	0.91742 <.0001	0.74704 <.0001	1.00000	0.80872 <.0001	0.80823 <.0001	0.90934 <.0001	0.71811 <.0001
CD CD	0.78059 <.0001	-0.57448 0.0009	0.82593 <.0001	0.84636 <.0001	0.80872 <.0001	1.00000	0.93268 <.0001	0.85713 <.0001	0.91638 <.0001
DSB DSB	0.79539 <.0001	-0.60570 0.0004	0.79222 <.0001	0.91331 <.0001	0.80823 <.0001	0.93268 <.0001	1.00000	0.90655 <.0001	0.96405 <.0001
DRB DRB	0.88378 <.0001	-0.79299 <.0001	0.90660 <.0001	0.81113 <.0001	0.90934 <.0001	0.85713 <.0001	0.90655 <.0001	1.00000	0.80334 <.0001
TB TB	0.70006 <.0001	-0.43943 0.0151	0.71868 <.0001	0.90218 <.0001	0.71811 <.0001	0.91638 <.0001	0.96405 <.0001	0.80334 <.0001	1.00000

Correlation among the parameters are significant at 5 % level of significance

N	Nitrogen
P	Phosphorus
K	Potassium
PH	Plant height
NB	Number of branches
CD	Collar diameter
DSB	Dry shoot biomass
DRB	Dry root biomass
TB	Total biomass

Stock quality is a product of interaction between genotype and nursery environment including management. Stock quality control through genetic manipulation is a long process, the alternative is to modify the nursery environment including cultural regime and stock handling practices. This study indicates that appreciable changes in stock quality can be made thigh nursery cultural practices by adopting appropriate cutting size and fertilizer application. *Salix* species is an important introduction in Punjab for diversified uses but required concerted research efforts for desired changes in stock quality.

CHAPTER-V

SUMMARY

Willows are very important tree species for the ecology and economy of countries in temperate and subtropical zones of the world. Willows belong to the genus *Salix*, family Salicaceae, are light demanding deciduous trees and shrubs, found primarily on moist soils in cold and temperate regions of the northern hemisphere. Willows provide a wide range of wood products (including industrial roundwood and poles, pulp and paper, reconstituted boards, plywood, veneer, sawn timber, packing cases, pallets and furniture), non-wood products (fodder, fuelwood) and services (shelter, shade, protection of soil, water, crops, livestock and dwellings). Work done on *Salix* in Punjab is very limited and not up to mark. Department of Forestry and Natural Resources have initiated to introduce promising clones from different sources for their testing. Present investigations were conducted to notify the effect of cutting size and nitrogen fertilizer on nursery stock of *Salix alba.*

In this study, 700 cuttings were collected from university seed farm, Ladhowal, Ludhiana of two sizes i.e. 0.50-1.50 cm and 1.51-2.50 cm. The total number of ten treatments were adjusted in randomized block experimental design. Observations such as plant height, collar diameter, number of branches, shoot biomass, root biomass, stock vigour index and sturdiness quotient were evaluated. The analysis of soil and plant NPK was done and for statistical analysis, CPCS1 software was used.

Results revealed that with increasing rate of nitrogen application, a significant and progressive increase in available nitrogen was noticed in both the cutting sizes, which resulted in improved nitrogen content in foliage of *Salix alba*. It implied that the increase in yield attributes were the consequence of beneficial effect of nitrogen emanating from the increased availability of nitrogen in soil and plants. A curvilinear relationship was observed when rates of nitrogen application were regressed with total biomass yield indicating that application of 150 kg N ha^{-1} was adequate to get optimum yield for both the cutting sizes. This signified that *Salix* responded significantly to N application @ 150 kg N ha^{-1} and resulted in 27.66 and 76.74 per cent increase in total biomass yield of 0.5-1.5 cm and 1.51-2.50 cm cutting sizes, respectively. The growth of *salix* with cutting size of 1.5-2.5 cm was found to be more superior as compared to 0.5-1.5 cm cutting size . So it is concluded that cuttings size of 1.5-2.5 cm gave better performance in all growth parameters as compared to cuttings size of 0.5-1.5 cm. Results revealed that the stock vigour index increases when nitrogen doses from 50-200 kg N/ha were applied. The impact is more noticeable from 50-150 kgN/ha rather than 150-200 kgN/ha.

It can be concluded from this study that application of 150 kg N ha^{-1} to *Salix* was adequate to get optimum total biomass yield and good quality planting stock for both the cutting sizes.

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