EFFECT OF MICROBIAL CONSORTIUM (BIO-FERTILIZER) ON GROWTH AND NUTRIENT UPTAKE OF POPLAR CLONES IN NURSERY

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
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MASTER OF SCIENCE
in
Forestry
(Minor Subject: Agronomy)

By
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(L-2014-A-71-M)

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LUDHIANA – 141004

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CERTIFICATE I

This is to certify that the thesis entitled, **"Effect of microbial consortium (Bio-fertilizer) on growth and nutrient uptake of Poplar clones in nursery"** submitted for the degree of M.Sc., in the subject of **Forestry** (Minor subject: **Agronomy**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Gurinder Singh** (Admn. No**. L-2014-A-71-M**) under my supervision and that no part of this thesis has been submitted for any other degree.

This 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 report entitled, **"Effect of microbial consortium (Bio-fertilizer) on growth and nutrient uptake of Poplar clones in nursery"** submitted by **Mr. Gurinder Singh (L-2014-A-71-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Forestry** (Minor subject: **Agronomy**) 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

The present study "Effect of microbial consortium (Biofertilizer) on growth and nutrient uptake by poplar clones in nursery" was conducted in teaching area, Department of Forestry and Natural resources, PAU, Ludhiana during the year 2015-2016. The influence of different doses of microbial consortium (biofertilizer) addition to nine different poplar clones in nursery on growth and nutrient uptake was studied. In present study different doses of bio-fertilizers showed the significant variation for collar diameter, leaf area, biomass accumulation, nitrogen, phosphorus and potassium concentration (%) except plant height and also revealed significant differences for accumulation of N, P and K. Study also revealed that the interaction between different doses of biofertilizers and clones shows the significant results for collar diameter, leaf area, plant height, nitrogen, phosphorus and potassium concentration(%) except in plant biomass. The application of microbial consortium (biofertilizers) increases the growth parameters, and nutrient uptake in plants. Application of microbial consortium resulted in enhanced growth for most of the characters and can be applied as alternative to chemical fertilizer for enhanced growth and better nutrient uptake in *Populus deltoides* plants.

Key words: *Populus deltoides*, Microbial consortium, Morphological growth parameters, N, P and K concentrations.

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

ਖੋਜ ਪ੍ਰਬੰਧ ਦਾ ਸਿਰਲੇਖ	:	ਨਰਸਰੀ ਵਿੱਚ ਪਾਪਲਰ ਦੇ ਕਲੋਨਾਂ ਦੇ ਵਿਕਾਸ ਅਤੇ ਪੌਸ਼ਟਿਕ ਤੱਤਾਂ ਨੂੰ ਗ੍ਰਹਿਣ ਕਰਨ ਦੀ ਸਮਰੱਥਾ ਉਪਰ ਮਾਈਕ੍ਰੋਬੀਅਲ ਕੰਸ਼ੋਰਸ਼ੀਅਮ (ਜੈਵਿਕ-ਖਾਦ) ਦੀ ਵਰਤੋਂ ਦਾ ਪ੍ਰਭਾਵ
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ਮੌਜੂਦਾ ਅਧਿਐਨ "ਸਾਲ 2015-2016 ਦੌਰਾਨ ਸਿੱਖਿਆ ਖੇਤਰ, ਜੰਗਲਾਤ ਅਤੇ ਕੁਦਰਤੀ ਵਸੀਲਿਆਂ ਵਿਭਾਗ, ਪੀ.ਏ.ਯੂ. ਲੁਧਿਆਣਾ ਵਿਖੇ ਵਿਕਾਸ ਅਤੇ ਪੋਸ਼ਕ ਤੱਤਾਂ ਨੂੰ ਵਧਾਉਣ ਲਈ ਮਾਈਕਰੋਬਾਇਲ ਕਨਸੋਰਟੀਅਮ (ਬਾਇਓਫਾਇਲਾਈਜ਼ਰ) ਦਾ ਅਸਰ" ਪਰਖਿਆ ਗਿਆ ਸੀ। ਵੱਖ-ਵੱਖ ਖੁਰਾਕਾਂ ਦਾ ਪ੍ਰਭਾਵ
ਮਾਈਕਰੋਬਾਇਲ ਕਨਸੋਰਟੀਅਮ (ਬਾਇਓਫਾਇਲਾਈਜ਼ਰ) ਦੇ ਇਲਾਵਾ ਵਿਕਾਸ ਅਤੇ ਪੌਸ਼ਟਿਕ ਤੱਤਾਂ ਬਾਰੇ ਨਰਸਰੀ ਵਿੱਚ ਨੌ ਵੱਖ-ਵੱਖ ਪੋਪਲਰ ਕਲੋਨ ਨੂੰ ਜੋੜ ਕੇ ਤਜ਼ਰਬੇ ਅਧੀਨ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ ਸੀ। ਸਾਡੇ ਅਧਿਐਨ ਵਿੱਚ ਬਾਇਓ ਖਾਦ ਦੀਆਂ ਵੱਖੋ-ਵੱਖਰੀਆਂ ਤੱਤ, ਕਾਲਰ ਵਿਆਸ, ਪੱਤਾ ਖੇਤਰ, ਬਾਇਓਮਾਸ ਸੰਚਵਾਣ, ਨਾਈਟ੍ਰੋਜਨ, ਫਾਸਫੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਤੱਤ (%) ਦੇ ਪੌਦੇ ਦੀ ਉਚਾਈ ਤੋਂ ਇਲਾਵਾ ਮਹੱਤਵਪੂਰਨ ਨਤੀਜੇ ਦਰਸਾਉਂਦੀਆਂ ਹਨ ਅਤੇ ਇਹ ਵੀ ਦੱਸਦੀ ਹੈ ਕਿ ਵੱਖਰੇ ਕਲੋਨ ਕਾਲਰ ਦੇ ਵਿਆਸ, ਪੱਤਾ ਖੇਤਰ, ਪੌਦਾ ਦੀ ਉਚਾਈ, ਬਾਇਓਮਾਸ ਜਮ੍ਹਾਂ, ਨਾਈਟ੍ਰੋਜਨ, ਕਲੋਨਜ਼ ਦੀਆਂ ਵੱਖੋ-ਵੱਖਰੀਆਂ ਖੁਰਾਕਾਂ ਦਰਮਿਆਨ ਸੰਵਾਦ, ਪੌਦੇ ਦੇ ਬਾਇਓਮਾਸ ਨੂੰ ਛੱਡ ਕੇ, ਕਾਲਰ ਵਿਆਸ, ਪੱਤਾ ਖੇਤਰ, ਪੌਦਾ ਉਚਾਈ, ਨਾਈਟ੍ਰੋਜਨ, ਫਾਸਫੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਤੱਤ (%) ਲਈ ਮਹੱਤਵਪੂਰਣ ਨਤੀਜੇ ਦਿਖਾਉਂਦਾ ਹੈ।ਮਾਈਕਰੋਬਾਇਲ ਕਨਸੋਰਟੀਅਮ (ਬਾਇਓਫਾਇਲਾਈਜ਼ਰ) ਦਾ ਕਾਰਜ ਵਿਕਾਸ ਮਾਪਦੰਡ ਵਧਾਉਂਦਾ ਹੈ ਅਤੇ ਪੌਦਿਆਂ ਵਿੱਚ ਪੌਸ਼ਟਿਕ ਤੱਤ ਮਾਈਕਰੋਬਾਇਲ ਕਨਸੋਰਟੀਅਮ ਦੀ ਵਰਤੋਂ ਕਰਨ ਨਾਲ ਵਾਧਾ ਅਤੇ ਵਿਕਾਸ ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ ਹੈ ਅਤੇ ਪੋਪੁਲਸ ਡਲੋਟੋਇਡਜ਼ ਪੌਦਿਆਂ ਵਿੱਚ ਬਿਹਤਰ ਵਿਕਾਸ ਅਤੇ ਵਧੀਆ ਪੌਸ਼ਟਿਕ ਤੱਤ ਲਈ ਰਸਾਇਣਕ ਖਾਦ ਦੇ ਵਿਕਲਪ ਵਜੋਂ ਵਰਤਿਆ ਜਾ ਸਕਦਾ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: ਮਾਈਕਰੋਬਾਇਲ ਕਨਸੋਰਟੀਅਮ, ਨਾਈਟ੍ਰੋਜਨ ਘਣਤਾ (%), ਫਾਸਫੋਰਸ ਘਣਤਾ, ਪੋਟਾਸ਼ੀਅਮ ਘਣਤਾ, ਮੋਰਫੋਲੋਜੀਕਲ ਵਿਕਾਸ ਮਾਪਦੰਡ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

India has quite meager area under forest (21.23%), which is far below the national target of 33 per-cent of its geographical area as laid out in our National Forest Policy (1988). The situation is more alarming in Punjab which has only 6.0 per cent of its geographical area under forest and tree cover. During the past few decades, forests have been cut at much faster rate than planted to meet the ever increasing demand for food, fuel wood, fodder, timber, etc.

Large scale deforestation has resulted in degradation of natural resources, erosion of fertile soils and reduction of water holding capacity of soil. There is an urgent need for substantial improvement in an increased production of forest resources, protecting existing forests and increase in forest productivity to meet the needs for fuel wood, timber and wood production on a sustainable basis.

In Punjab, which is predominantly an agricultural state and where more than 84 per cent of area is under crop cultivation, there is little possibility of increasing the area under forests by sole planting of trees. The only way to increase the area under forests is through diversification of area from wheat-paddy rotation to agroforestry, which involves the integration of trees with agricultural crops on the same piece of land. This will require growing of tree species with high commercial value, fast growth rate, multiple utility and with ability to improve soil fertility.

However, farmers are now more interested in planting fast growing tree species like Eucalypts, poplar, drek etc. There is an urgent need for undertaking large scale afforestation of poplar owing to its large scale mortality in the recent past, its commercial importance in rural livelihood and depleting forest resources. Production of healthy and vigorous planting stock is a prerequisite for the success of any afforestation programme. Fertilization is one of the various important factors for the production of quality planting stock in nursery.

In Punjab, poplar is reliable option for agroforestry. It is very important taxonomical group of tree species in plantation forestry because it is a deciduous fast growing. It has been successfully cultivated as a forest crop or agro-forestry crop in Punjab plains. In India, poplar occupies an important place amongst fast growing tree species due to its multiple uses and its cultivation has specifically gained importance in social forestry and agroforestry practices. Recently, it is one of the leading potential species for silvi-culture biomass production.

Fertilizer requirement varies from species to species. Therefore, there is need to find out the optimum dose of different nutrients for proper growth of plants. Continuous and excessive use of chemical fertilizers is not only uneconomical but also affects the soil health.

Therefore, there is urgent need for integrated nutrient management involving both chemical and biofertilizers. Biofertilizer are eco-friendly and do not have any adverse effect on the soils fertility. They not only help in enhancing the plant growth but also help in uptake of nutrient from the soil. In recent years, biofertilizers have been used and found effective in improving, the various agricultural and fruit crops. However, such information is scanty for forest tree species.

There is an important need of vigorous and healthy planting stock production. In the nursery, the healthy successful seedling production is considered to be an important factor, judicious fertilizer application is one of the important management factor and maintains healthy soil as the excess and inadequate fertilizer dose for the plant growth is harmful. The fertilization in excess is toxic to plant and uneconomical (Awodola 1993). The type and amount of fertilizers can be varied as per the species requirement of difference in soil fertility and nutrients required. Application of biofertilizers accelerates the extent of nutrient availability, supplements the demand of chemical fertilizers and enhances the growth and biomass of plants (Paroha *et al* 2000).

Poplar nursery needs well drained fertile soil with assured irrigation for raising nursery stock. The soils used to raise nursery are generally low in microbial population and nutrients. So, in order to raise the production quantitatively growers are applying chemical fertilizers at alarming rates, which adversely affect the soil biology by affecting the natural useful activities of soil microbes and increase the cost of raising quality nursery. In order to raise a quality nursery stock grower had to provide a potential nutrient supplier which is available for plant in a soil to supply nutrients gradually and production cost of such nutrient supplier should be lower than other chemical fertilizers. Microorganisms present naturally in soil have vital role in fixing/ solubilizing/mobilizing/ nutrient recycling but their populations are often scanty. In order to increase the stock quality, the desired microbes from rhizosphere are isolated and artificially cultured in adequate count and mixed with suitable carriers or as they are in suitable combinations (microbial consortium) by artificial culturing.

The activity of soil micro-organisms is important for growth and establishment of seedlings. Microbial consortium provide beneficial micro-organism in plant rhizosphere, which increase the availability of nutrients for plants in the rhizosphere by fixing nitrogen, by solubilizing bound nutrients (phosphorous) and making it available to plants.

The work done in global literature is very little in the biofertilizers efficacy on forest crops particularly poplar. Therefore, the objective of the present investigation is as under;

1. The effect of microbial consortium (bio-fertilizer) on the growth of recommended

poplar clones (viz. PL-1, PL-2, PL-3, PL-4, PL-5, PL-6, PL-7, L-47/88, L-48/89) in nursery.

2. The effect of microbial consortium (bio-fertilizer) on the nutrients uptake by recommended poplar clone in nursery.

CHAPTER II

REVIEW OF LITERATURE

How essential is the nutrient application as a study has been shown for the proper plant growth. The plant uptake of the nutrients making soil depletion as the vital element, thus imperative is that enough potential is required in the soil so as it provides nutrients to the plant system (Nagaveni and Vijayalakshmi 2002). For augmenting the nutrient status of the soil, fertilizer are required to be added in the soil in order to compensate for the loss due to leaching and uptake by the plant (Mohan 1992). Excessive application of chemical fertilizers may result in deterioration of soil fertility and soil pollution. Although a lot of work has been done on the role of nitrogen and phosphorus fertilizer in presence and absence of biofertilizer in agricultural crop but literature on these aspect in forest tree species, particularly legume tree species, is meager. The role of inorganic and biofertilizers, alone or in combination on plant growth from the available literature was reviewed and presented in this chapter as under:

2.1 Biofertilizer effect on Plant nutrients and growth

Biofertilizers are fertilizers, processed through the use of micro-organisms viz. *Rhizobium, Azotobacter, Azospirillum, Bacillus,* Mycorrhiza etc. (Subbarao 1984). They stimulate plant growth by providing necessary nutrients by their colonization in the Rhizosphere. The Rhizosphere, affected through microbial activities, modifies the plant by providing growth substance and increased availability of nutrient element (Jakobsen *et al* 1994). Biofertilizer are eco-friendly and do not have any ill effect on soil health and environment. They are low cost inputs and have high benefit-cost ratio. Some microorganisms also secrete antibiotics which reduced pathogen and increased resistance to diseases (Mahajan *et al* 2003).

Biofertilizer are the organisms (bacteria, fungi, cyano bacteria, etc.) that enrich the soil with nutrients. Plants have a number of beneficial relationships with such organisms. The importance of these fungi to agricultural and forestry resides in their role in plant growth and nutrition. Dual inoculation of such fungi with a *Rhizobium* and other bacterium on plant enhance the growth and other beneficial effects viz, resistance to disease and tolerance to adverse soil and climatic condition (Sadhana 2014).

In India soil fertility is diminishing gradually due to soil erosions, loss of nutrition, accumulation of toxic elements, water logging and unbalanced nutrient compensation. Organic manure and bio fertilizers are the alternate sources to meet the nutrient requirement of crops, biofertilizers, benefiting the crops are *Azotobacter, Azosprillium, Phosphoobacter* and *Rhizobacter* which are very important. The role of biofertilizer in agricultural production is of great importance. Inoculation of nitrogen fixing bacteria with biofertilizers increases the phosphorous level that influences the sunflower seed oil content and the proportion of fatty

acids (unsaturated/saturated fatty acids ratio). Biofertilizers can also make plant resistant to adverse environmental stresse4s. Control of root-knot diseases of soybean caused by *Meloidogyne javanica* may be explored through use of BAU-Biofungicide and BINA-Biofertilizer for eco-friendly management of this disease avoiding chemical nematicides (Bhattacharjee *et al* 2014)

Many researches showed that the growth, yield and quality parameters of certain plants significantly increased with biofertilizers containing bacterial nitrogen fixer, phosphate and potassium solubilizing bacteria and microbial strains of some bacteria. These bacteria reduced the population of *Meloidogyne incognita* infecting chilli and tomato and *Tylenchulus semipenetrans* on Washington navel orange. Also, Six new commercial Egyptian bio-fertilizers viz., nitrobien, rizobacterin, cerealin, phosphorine, microbien, blue green algae, and five new commercial Egyptian plant nutrients viz., nuftarein, potassein F, citrein, kotangein and kapronite as for the control of root-knot nematode, *Meloidogyne incognita* on sunflower. All the tested products significantly reduced the numbers of juveniles in soil, and galls, females, eggmasses on roots. Also, nitrobien and phosphorine were effective in reducing *M. incognita* population infecting cowpea and enhancing plant growth criteria (Youssef and Eissa 2014).

Current soil administration systems are chiefly subject to inorganic substance based manures, which made a genuine risk human wellbeing and condition. The misuse of gainful organisms as a biofertilizer has turned out to be vital significance in horticulture area for their potential part in nourishment wellbeing and practical harvest creation. The eco-accommodating methodologies rouse an extensive variety of utilization of plant development advancing rhizobacteria (PGPRs), endo-and ectomycorrhizal parasites, cyanobacteria and numerous other helpful infinitesimal living beings prompted enhanced supplement take-up, plant development and plant resistance to abiotic and biotic anxiety. The present audit highlighted biofertilizers intervened crops practical qualities, for example, plant development and profitability, supplement profile, plant resistance and insurance with uncommon accentuation to its capacity to trigger different development and safeguard related qualities in flagging system of cell pathways to cause cell reaction and accordingly edit change. The information picked up from the writing assessed in this will help us to comprehend the physiological bases of biofertlizers towards maintainable agribusiness in lessening issues related with the utilization of chemicals manures (Bhardwaj *et al* 2014).

Although, there are numerous research studies on effect of biofertilizer on agricultural crops (Tewari 1985 and Yong *et al* 1988) but reports are scanty on forest tree species. The work done on effect of mycorrhizal and *Rhizobium* inoculation, singly and dually, on plant growth and nutrient uptake has been reviewed and presented here.

2.2 Effect of Microbial consortium inoculation

The effect of *microbial consortium* consisting plant growth promoting rhizobacteria (PGPR) *Azotobacter, Bacillus* and *Pseudomonas* were tested separately and in combination of *Glorious superba*. The combinations od above mentioned PGPR strains significantly increased plant height, chlorophyll and protein content in G. *superba* when compared to the un inocultated control, PGPR exhibit direct and indirect indirect mechanisms as plant growth promoters and biological control agents. Direct mechanism by PGPR; include the provision of bio-availabile phosphorouys for plant uptake, nitrogen fixation for plant. The results of this study suggest that PGPR applied in combinations have the potential to increase the plant growth, chlorophyll and protein content of G. *superba* (Megala and Elango 2012).

PGPR play a significant role in enhancing plant growth and development both under non-stress conditions by a number of direct and indirect mechanisms (Khalid *et al* 2004, Glick *et al* 2007 and Naddeem *et al* 2010). The mechanisms that promote palnt growth regulators and organic acids as well as protection by enzymes like ACC-deaminase, chitinase and glucanase (Glick *et al* 2007 and Hayat *et al* 2010).

The effect of microbial consortium consisting Plant Growth Promoting Rhizobacteria (PGPR) like *Azospirillum, Azotobacter, Pseudomonas* and *Bacillus* were tested separately and in combination on *Withania somnifera* for two consecutive years (2009 and 2010). The combinations of above mentioned PGPR strains significantly increased plant height, root length, and alkaloid content in *Withania somnifera* when compared to the uninoculated control. Plant growth promoting rhizobacteria (PGPR) had exhibit direct and indirect mechanisms to enhance plant growth as growth promoters and biological control agents. Direct mechanism by PGPR, include the provision of bio-available phosphorus for plant uptake, nitrogen fixation for plant. The results of this study suggest that the PGPR applied in combination have the potential to increase the plant growth, alkaloid content of *Withania somnifera* (Rajasekar and Elango, 2011). *Azospirillum* is attributed mainly to increased root development and thus to increased rates of water and mineral uptake Some plant-growth promoting bacteria solubilize phosphate from either organic or inorganic bound phosphates, thereby facilitating plant growth (Lipton *et al* 1987 and Vassilev *et al* 2006). Plant growth promotion is caused by the production of plant growth factors such as IAA, gibberellins and cytokinins.

The capacity for rhizobacteria and growth to go about as bioprotectants by means of actuated systemic resistance has been illustrated, and impressive advance has been made in explaining the instruments of plant–biocontrol agent–pathogen cooperations. Pseudomonas aeruginosa PJHU15, Trichoderma harzianum TNHU27, and Bacillus subtilis BHHU100 from rhizospheric soils were utilized independently and in consortium and evaluated on the premise of their capacity to give infection insurance by relating changes in ascorbic corrosive and

hydrogen peroxide (H_2O_2) creation, lipid peroxidation, and cell reinforcement compounds in pea under the test of Sclerotinia sclerotiorum. Expanded creation of H_2O_2 24 h after pathogen challenge was watched and was 254.4 and 231.7–287.7 % higher in the triple consortium and separately treated plants, individually, when contrasted with untreated tested control plants. Essentially, lipid peroxidation achieved a most extreme at 72 h of pathogen challenge and was 61.2 and 11.2–32.1 % less in the triple consortium and independently treated plants, separately, when contrasted with untreated tested control plants. These discoveries recommend that the association of microorganisms in the rhizosphere upgraded assurance from oxidative anxiety created by pathogen assault through acceptance of cancer prevention agent chemical and enhanced responsive oxygen species administration (Jain *et al* 2013).

Consortium involve soil bacteria able to colonize the surface of the root systems (and sometimes root inner tissues) and to stimulate the growth and health of the plant, and are reffered to as employed by soil microorganisms include: (1) release of complexing or mineral dissolving compounds e.g. organic acid anions, siderophores, protons, hydroxyl ions, CO_2, (2) liberation of extracellular enzymes (biochemical P mineralization (McGill and Cole 1981).

To evaluate *Azospirillium brasilense, Azotobacter chrococcum, Bacillus megatrium*, *phosphaticum* and *Trichodrema viride* for their ability to solubilize nutrients end to develop a microbial consortium for plant growth promotion in sunflower (Amalraj *et al* 2012).

It has been suggested that development of plant growth promoting consortium (PGPC) cloud be feasible strategy for increased activity and better viability of plant growth promoting rhizobacteria (PGPR). When these strains are made into an inoculums consortium, each of the constituents strains of the consortium not only out competes with the others for rhizospheric establishments, but complement functionality for plant growth Promotion (Shenoy and Kalagudi 2005).

2.3 Effect of *Rhizobium* inoculation

Rhizobium, living in symbiotic association with leguminous plants was first isolated by Beijerinck (1888). Leguminous trees are ubiquitous in nature. Most of the leguminous species form nodules in the roots in symbiotic association with *Rhizobium* and fix atmospheric nitrogen. Occurrence of nodules in different tree legumes was first reported by Allen and Allen (1981). The role of *Rhizobium* bacteria in trapping atmospheric N, thereby, enriching soil fertility is well established in agriculture. However, its role in plantation forestry needs to be explored at length.

Basu and Kabi (1987) reported enhanced plant height, dry matter content nodule number and nodule weight in *Rhizobium* inoculated seedlings over uninoculated control in *Dalbergia sissoo* and leguminous tree species. Jamaluddin *et al* (1995) studied the effect of four *Dalbergia sissoo, Leucaena leucocephala, Pongamia pinnata* and *Albizia lebbeck* on the growth. *A lebbeck* seedling in the nursery and observed grater shoot dry weight, nitrogen

content and number of nodules in inoculated seedlings than uninoculated seedlings. Totey *et al* (1997) studied the effect of *Rhizobium* inoculation on growth of seedlings and seed germination of *Dalbergia sissoo*. Seed inoculation of *Rhizobium* biofertilizer for twenty-four hours significantly increased the seed germination and shoot height of three week old seedlings as compared to control. However, Sharma and Dutta (1994) reported non-significant increase in germination of *Rhizobium* inoculated seeds of *Dalbergia sissoo*, *Acacia auriculiformis* and *A. catechu*.

Vafadar *et al* (2013) research recovered plantlets of stevia in tissue culture is moved to pots in nursery and vaccinated with plant-development advancing rhizobacteria (PGPRs) (*Bacillus polymixa, Pseudomonas putida*, and *Azotobacter chroococcum*) and arbuscular mycorrhizal growth (AMF) (*Glomus intraradices*). The outcomes demonstrated that in contrast with control, immunization with a solitary microorganism, essentially expanded root and shoot biomass and in addition stevioside, chlorophyll, and NPK content in plants. Be that as it may, such expanded impacts have been observed to be additionally upgraded altogether because of double perfect blends of inoculants coming about because of their solid synergistic connections among themselves. All development parameters recorded the most noteworthy in 60-days-old plants in the treatment of *Glomus-Azotobacter* and taken after with *Glomus-Bacillus* and *Azotobacter-Pseudomonas* medicines, separately. Moreover, elite fluid chromatography (HPLC) chromatograms uncovered that the most stevioside content have been delivered in same medications. Triple medicines had less constructive outcomes contrasted with double vaccinations. Likely ability between microorganisms in triple immunizations has decreased their productivity. In this way, appropriate mix of mycorrhizal organisms and PGPR as biotic elicitors can upgrade development and stevioside content in tissue culture-recovered plantlets of stevia.

Three *Rhizobium* isolates from different localities were assessed in nursery conditions for enhancing growth in *Dalbergia sissoo*. Growth and biomass increment of inoculated seedlings were significantly higher than control (Sah *et al* 1998). Basavaraju (1986) reported significant effect of various *Rhizobium* isolates on the improvement in dry matter production and protein yield of *Leucaena leucocephala*. Tang (1994) observed increased shoot dry weight, nitrogen uptake and number of nodules in *Leucaena leucocephala* seedling inoculated with *Rhizobium* treatment. Purohit *et al* (1995) observed the effect of *Rhizobia* culture on *Albizia stipulata, Ougeinia dalbergioides* and *Dalbergia serica* under nursery conditions. Seedling survival was better in inoculated seedlings than control. However differences in growth between inoculated and uninoculated seedling were found to be non-significant. Sengupta and Chaudhari (1995) studied the effect of *Rhizobial* inoculation on the growth of *Sesbania grandiflora* in coastal sand dune soil and reported significant improved growth in terms of plant height, leaflet number, shoot dry weight, nodule number and nodule biomass.

Seeds of four leguminous tree species *Millettia leucantha, Xyliaxy locarpa, Pterocarpus rnacrocarpus* and *Dalbergia cultrata* were inoculated with the eight strains of *Rhizobium*. Seedlings were grown for two months results showed significant increase in plant height, diameter and dry biomass of shoot and root (Klivetong 1996). Kaushal (1996) reported significant increase in biomass production nodule number, nodule biomass, total N uptake and amount of N fixed in *Albizialebbeck* due to *Rhizobial* inoculations over uninoculated seedlings (control). Kang and Li (1998) studied growth response of *Acacia* seedlings to *Rhizobial* inoculation. Height, total biomass and nodule biomass in inoculated seedlings were increased as compared to control.

The effect of *Rhizobial* inoculation on plant growth and nodulation in *Albizia procera, A. lebbeck* and *Leucaena leucocephala* in sterilized and non-sterilized soil was studied by Aryal *et al* (1999). *Rhizobium* inoculation enhanced plant growth, nodulation and biomass production in all the species. *Rhizobium* inoculated seedlings showed significantly higher growth for seedling height, collar diameter, root length, number of branches, number of nodules, biomass production and N and P uptake as compared to control in *Acacia catechu* and *Acacia mollissima* (Banyal and Bhardwaj 2003).

The growth response of *Acacia auriculiformis* seedlings inoculated with six strains of *Rhizobium* were studied under nursery conditions. Six months after inoculation, the plant height and diameter of seedlings increased by 1.1 to 44.8% and 6.8 to 26.2%, respectively, as compared to control (Zhang *et al* 2005).

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled, "Effect of microbial consortium (Bio-fertilizers) on growth and nutrient uptake by poplar clones in nursery" was carried out in teaching area of Department of Forestry & Natural Resources at Punjab Agricultural University, Ludhiana during the year 2015-16. Soil and plant analysis were carried out in Department of Soils. The experimental details and the methodology adopted for conducting the study are described in this chapter.

3.1 Collection of clonal material, Biofertilizers and layout of the experiment

Nine commercial clones viz. PL-1, PL-2, PL-3, PL-4, PL-5, PL-6, PL-7, L-47/88, L- 48/89 were recommended by department of Forestry and Natural Resources, Punjab Agricultural University and collected from research area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana (Punjab). Biofertlizers comprising *Azotobacter, and psudomonos* grown on respective culture were obtained from Department of Microbiology, Punjab Agricultural University, Ludhiana. The different treatments in respect of biofertilizers consist of microbial consortium of 0, 6, 8 and 10 Kg per acre was applied through soil during last week of March in nursery of different clones of Poplar. The experiment was laid out in two factor factorial completely Randomized design.

3.2 Experimental site

3.2.1 Location and climate

Ludhiana is situated at an elevation of 244 metres above mean sea level with a latitude of 30° 56' North and longitude of 75° 52' East. May and June were the hottest months whereas; December and January are the coldest. Frost occurrence is not common. On an average site received 704 mm rainfall, which is not evenly distributed and most of it i.e. 75-80 % is received during July and September. The site is described by hot and dry summers and chilly winters. Climate of site is sub-tropical to tropical with a long dry season from late September to early June and wet season from July to September. May and June were the most sweltering months while; December and January are the coldest.

3.2.2 Soil characteristics

The characteristics of the soil used for filling the polybags are shown in Table 3.1.

Table 3.1: Physico-chemical characteristics of experimental soil

Parameter	Test value	Method Employed
Texture	Silty loam	International Pipette method (Piper 1966)
pH (1:2 soil : water suspension)	7.4	Beckman's Glass electrode pH meter (Jackson 1967)
Organic carbon (%)	0.45	Rapid Titration Method (wet Digestion) (Walkley and Black 1934)
Available N (kg ha^{-1})	180	Alkaline potassium permanganate method (Subbiah and Asija 1956)
Available P (kg ha^{-1})	10	Sodium Bicarbonate Extractable P (Olsen e*t al* 1954)
Available K (kg ha^{-1})	298	1N NH_4OAC Extractable K method (Merwin and Peech 1950)
Electrical conductivity (1:2) dsm^{-1}	0.52	Solubridge Conductivity Meter (Richard 1954)

3.3 Observation recorded

3.3.1 Morphological characters

All morphological parameters were recorded during last week of December (2015), except average leaf area which was recorded in the month of June (2015).

3.3.1.1 Plant height (cm)

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

3.3.1.2 Collar diameter (mm)

The diameter of the plants in the nursery was measured with the help of digital caliper at the collar region.

3.3.1.3 Plant fresh weight

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

3.3.1.4 Plant dry weight

The uprooted plants were first dried in the sunlight and then in oven at 60 ± 2^0C till constant weight were obtained and plant shoot and root dry weight was recorded separately in grams.

3.3.1.3 Leaf area (cm^2)

Three plants of each clone from each treatment were selected randomly during the month of June. Further from each plant six fully expanded leaves were selected for leaf area measurement by using portable leaf area meter (CID 110, CID INC, and USA). The average of these six leaves is taken and further average of leaves selected from three plants of one clones give a measurement of leaf area of that clone.

3.3.2 Plant analysis

Leaf samples were collected from each replication in each treatment for plant analysis. Recently matured and fully expanded leaves were plucked, free from any type of disease and then washed with distilled water. After that those leaf samples were air dried for 2-3 days then dried in a hot air oven at 60-70°C for 24 hr for complete drying. Grind the samples and sieved it through 72 mesh size sieve and keep it in polythene bags for nutrient analysis. Samples were collected from September to November regularly on monthly basis during 2015.

3.3.2.1 Nitrogen

Plant material (0.5 g) was processed in concentrated H_2SO_4 with assimilation blend comprising K_2SO_4, $CuSO_4$, Se and HgO. After assimilation, the concentrate acquired was broke down for N utilizing a Kjeldhal gathering as per system outlined by Jackson (1973).

3.3.2.2 Phosphorus and potassium

The plant samples were digested using diacid (3 HNO_3, 1 $HC1O_4$) according to the procedure detailed by Piper (1966). The P in leaves is estimated spectro-photometrically by molybdo-vanado phosphoric acid method (Sparks *et al* 1996) and K content was analyzed with the help of flame photometer (Pratt 1982).

3.4 Statistical analysis

The data were analyzed statistically in two factor factorial analysis for the assessment of analysis of variance for morphological characters and plant nutrient analysis (Panse and Sukhatme 1989). Data were analyzed using OPSTAT software.

3.4.1 Critical difference (CD)

In order to compare the mean of various entries, the critical difference was calculated by following the formula:

C.D. = S.E. x $t_{0.05}$ (error degree of freedom)

Where, SE is standard of error

S.E. = $(2\ MSE/R)^{1/2}$

Where, MSE = error mean sum of square

R = Number of replications

T = Tabulated value of t at 5% level of significance

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of bio-fertilizers on growth and nutrient uptake by poplar clones in nursery" was undertaken to study the influence of biofertilizers on growth performance and uptake of plant nutrients in *Populus deltoides* entire transplants production in nursery. The results are presented and discussed accordingly with the support of available literature in this chapter.

4.1 Morphological characters

4.1.1 Collar diameter of poplar ETP's as influenced by microbial consortium and clones and in nursery

Collar diameter of poplar ETP's in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plants for collar diameter as affected by biofertilizers application and their interactions are given in Table 4.1. It was observed that different levels of biofertilizers showed a significant difference for collar diameter. Among the different biofertilizer rates, maximum collar diameter was recorded with application of biofertilizer @10 Kg/acre with mean value (18.98 mm) which was statistically at par with level of 8kg/acre having mean value (18.78mm) and level of 6kg/acre with mean value (17.32 mm) but significantly higher as compared to control having mean value (16.02 mm). Mandal and Kaushik (1995) also demonstrated significant increase in collar diameter in *Acacia nilotica* seedlings with dual inoculation of AM fungi and *Rhizobium* as compared to uninoculated control. Jamaluddin *et al* (2004) also reported significantly increased in collar diameter in *Albizia lebbeck.*

It was observed that among the different genotypes exhibited significant difference with respect to collar diameter. Among the different clones of poplar maximum collar diameter was observed in clone PL-7 having mean value of 19.36mm which is significantly higher than all other clones. The order of clones for decrease in collar diameter was PL-7-(19.36mm) > PL-2 (18.52mm) > L-47/88 (18.35mm) > PL-6 (18.09mm) > L-48/89 (18.02 mm) > PL-1 (17.90mm) > PL-3 (16.99mm) > PL-4 (16.80mm) > PL-5 (15.78mm).

It was observed that interaction effect between biofertilizer and clone was found significant with respect to collar diameter. Among the different interaction maximum collar diameter was observed in interaction between biofertilizer application rate 8kg/acre and clone PL-7 having value of (21.18mm) and minimum collar diameter was observed in interaction between biofertilizer application rate 6kg/acre and clone PL-4 having value of (14.14mm). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of collar diameter of poplar ETP's production in nursery.

Table 4.1: Collar diameter (mm) of poplar ETP's as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	**6**	**8**	**10**	
PL 1	17.10	17.50	17.98	19.05	17.90
PL 2	16.37	17.94	18.79	20.98	18.52
PL 3	14.48	15.34	18.70	19.43	16.99
PL 4	14.14	16.80	19.12	17.12	16.80
PL 5	14.19	14.74	16.50	17.68	15.78
PL 6	16.22	18.89	18.98	18.27	18.09
PL 7	18.73	17.45	21.18	20.09	19.36
L-47/88	16.52	18.82	19.46	18.58	18.35
L-48/89	16.41	17.57	18.38	19.70	18.02
Mean	**16.02**	**17.32**	**18.78**	**18.98**	
Factor	**C.D at (0.05)**				
Clone	0.41				
Biofertilizer	0.20				
Clone x Biofertilizer	0.83				

4.1.2 Plant height of poplar ETP's as influenced by microbial consortium and clones and in nursery

Plant height of poplar ETP's during September in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for height as affected by biofertilizers application and their interactions given in Table 4.2. It was observed that among the different doses of biofertilizers level for height shows significant difference with respect to plant height. Data depicted that maximum height was recorded in biofertilizer application at 10 kg/acre having a mean value (474.37 cm) and which is significantly higher than control having mean value of (409.79 cm) statistically at par with all other treatments having mean value 6kg/acre(447.07 cm) and 8kg/acre (457.27 cm).

The data in table 4.2 showed that there is a significant increase in the plant height among the different clones. Maximum height was recorded in clone PL-1 with mean value of (473.15cm) which is significantly superior to all other clones. The order of clones for decrease in plant height was PL-1(473.15cm) PL-7 (465.31cm) > PL-5 (452.10 cm) > PL-6 (448.40cm) > PL-2 (444.97cm) > L-47/88 (441.29cm) > L-48/89 (436.08cm) > PL 4 (432.42 cm) > PL-3 (404.43cm) .

It was observed that interaction effect between biofertilizer and clone was observed significant with respect to plant height. Among the different interaction maximum height was observed in interaction between biofertilizer application rate 8kg/acre and clone PL-7 having value of (523.17cm) and minimum plant height was observed in interaction between biofertilizer application rate 8kg/acre and clone L-47/88 having value of (406.38cm) The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of plant height of poplar ETP's production in nursery.

4.1.3 Average leaf area per leaf of poplar as influenced by microbial consortium and clones and in nursery

Leaf area of poplar during first week of November in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for leaf area as affected by biofertilizers application, genotypes and their interactions given in Table 4.3. It was observed that among the different doses of biofertilizers level for leaf area shows significant difference with respect to leaf area. Data depicted that maximum leaf area was recorded in biofertilizer application at 10 kg/acre having mean value of (401.79 cm^2) and which is significantly higher as compared to control with mean value (345.67cm^2) and application at 6 kg/acre with mean value of (396.01 cm^2) and is statistically at par with biofertilizer application at 8 kg/acre having leaf

Table 4.2: Height (cm) of poplar ETP's as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	428.35	479.47	496.58	508.190	473.15
PL 2	425.24	451.24	450.20	463.21	444.97
PL 3	281.23	404.84	439.32	456.35	404.43
PL 4	420.74	437.32	435.34	436.30	432.42
PL 5	473.33	495.39	426.21	473.46	452.10
PL 6	419.24	483.51	440.28	470.57	448.40
PL 7	407.29	423.17	507.61	523.17	465.31
L-47/88	406.38	413.45	468.75	476.58	441.29
L-48/89	426.39	435.31	451.14	461.50	436.08
Mean	409.79	447.07	457.27	474.37	
Factor	**C.D (0.05)**				
Clone	32.37				
Biofertilizer	35.00				
Clone x Biofertilizer	64.74				

Table 4.3: Average Leaf area per leave (cm^2) of poplar as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	371.66	396.91	388.39	389.45	386.60
PL 2	324.72	370.87	362.38	364.41	355.56
PL 3	357.55	401.11	423.34	424.12	401.53
PL 4	382.20	357.64	340.56	345.54	356.46
PL 5	290.29	405.78	462.77	462.56	405.35
PL 6	361.32	398.63	394.09	396.78	387.70
PL 7	322.04	397.13	392.61	389.65	375.36
L-47/88	350.69	420.26	419.19	419.34	402.37
L-48/89	350.55	418.29	424.77	423.89	404.37
Mean	345.67	396.91	400.89	401.79	
Factor	**C.D (0.05)**				
Clone	3.47				
Biofertilizer	3.69				
Clone x Biofertilizer	6.93				

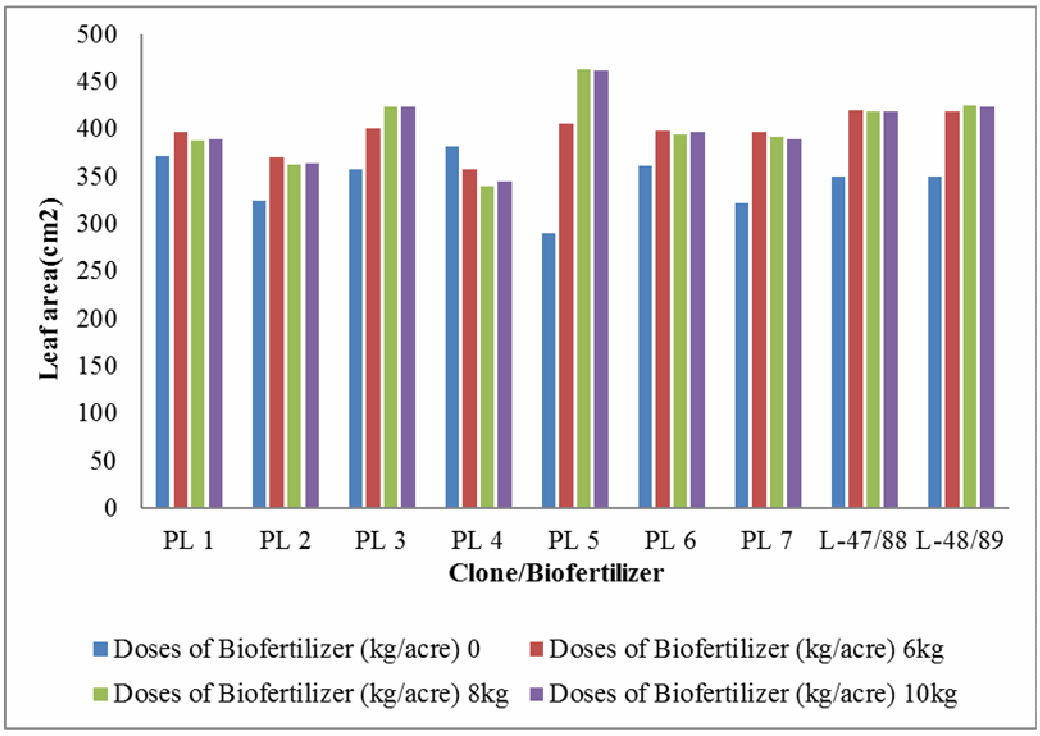

Fig. 1: Graphical representation of leaf area influenced by treatments

area (400.89cm^2).

The data in table 4.3 showed that there is a significant increase in the leaf area among the different clones. Among the different clones maximum leaf area was recorded in clone PL-5 with leaf area of (405.35cm^2) which is significantly higher than clone PL-1with area of (386.60 cm^2), PL-2 with mean value of (355.56cm^2), PL-4 with leaf area of (356.46cm^2), PL-6 with mean value for leaf area (387.70cm^2)andPL-7 having mean value (375.36cm^2) and is statistically at par with clonePL-3 having area of (401.53cm^2), PL-8 with leaf area (402.37cm^2), PL-9 having mean value of (404.37cm^2)

The data in table 4.3 showed interaction effect between biofertilizer and clone was observed significant with respect to leaf area. Among the different interactions maximum leaf area was recorded in interaction between biofertilizer application rate 8kg/acre and clone PL-5 having mean value of (462.77cm^2)and minimum leaf area was recorded in interaction between clone PL-5 and control with leaf area (290.29cm^2). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of leaf area of poplar ETP's production in nursery. The graphical presentation of data for leaf area is given in Fig. 1.

4.1.4 Biomass of poplar ETP's as influenced by microbial consortium and clones and in nursery

Biomass of poplar ETP's in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for biomass as affected by biofertilizers application, genotypes and their interactions given in Table 4.4. It was observed that among the different doses of biofertilizers level for biomass shows significant difference with respect to biomass. The significant variation in biomass due to microbial consortium application is observed in the present study, these results are in line with the results by Rajendran and Jayashree (2007) reported that significant enhancement in shoot fresh weight of *Acacia nilotica* seedlings with dual inoculation of AM fungi and *Rhizobium* as compared to uninoculated control

The data indicated in Table 4.4 showed that there is a significant differences among different doses of biofertilizers levels for biomass accumulation. Data depicted that maximum biomass accumulation was recorded in biofertilizer application at 10 kg/acre with biomass (3.201 kg) and which is significantly higher as compared to control having mean value for biomass (3.026 kg) and application at 6 kg/acre with biomass (3.044 kg) and is statistically at par with biofertilizer application at 8 kg/acre with mean value of (3.145 kg).

Table 4.4: Biomass (kg) of poplar ETP's as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL-1	2	2.02	2.523	2.85	2.348
PL-2	2.68	2.727	2.956	2.781	2.786
PL-3	2.737	2.837	2.777	2.893	2.811
PL-4	3.027	2.97	2.989	3.592	3.144
PL-5	3.643	3.513	3.523	3.503	3.545
PL-6	2.983	3.023	3.21	2.973	3.047
PL-7	3.023	3.035	3.193	3.017	3.067
L-47/88	3.6	3.623	3.548	3.53	3.575
L-48/89	3.537	3.643	3.587	3.663	3.607
Mean	3.026	3.044	3.145	3.201	
Factor	**C.D (0.05)**				
Clone	0.14				
Biofertilizer	0.15				
Clone x Biofertilizer	N.S				

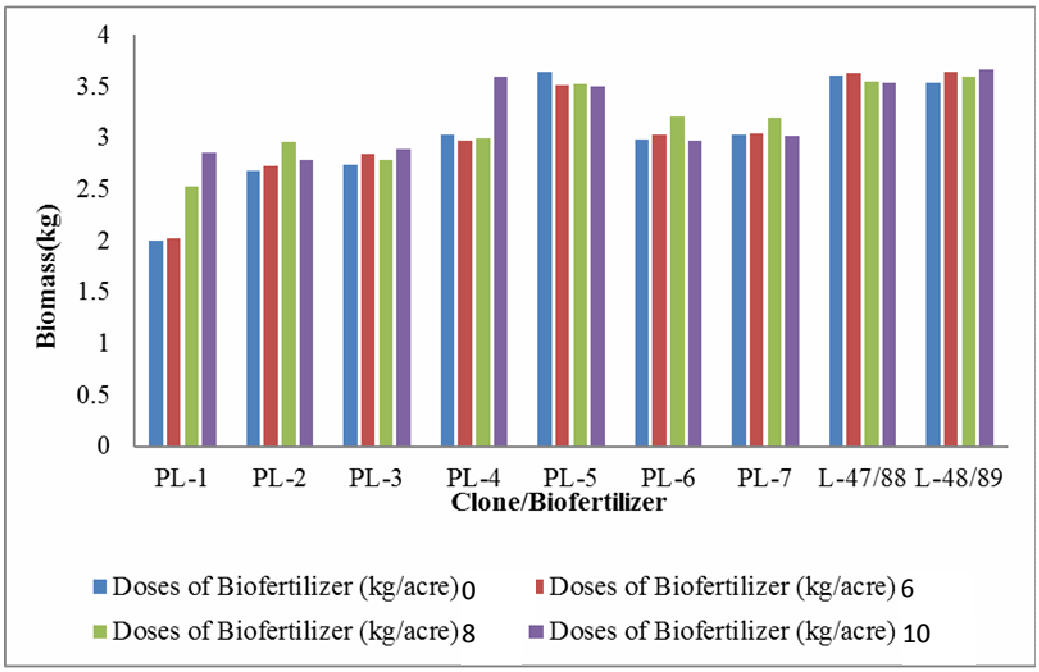

Fig. 2: Graphical representation of plant biomass influenced by treatments

The data in table 4.4 revealed that there is a significant differences among different clones with respect to biomass accumulation. Among the different clones maximum biomass accumulation was recorded in clone L-48/89 with biomass of (3.607 kg) which is significantly higher than clones PL-1 with mean value of (2.348 kg), PL-2 with biomass (2.786 kg), PL-3 having mean value of (2.811 kg), Pl-4 with value of (3.144 kg), PL-6 with biomass of (3.047 kg) and PL-7 with mean value of (3.067 kg) and statistically at par with clones PL-5 having mean value of (3.545 kg), L-47/88 having biomass of (3.575 kg).

The interaction between biofertilizer and clone is found non significant for biomass accumulation. Maximum biomass accumulation was recorded in interaction biofertilizer application rate 10kg/acre and clone L-48/89 with biomass of (3.663 kg) and minimum biomass accumulation was recorded in interaction between clone PL-1 and control with mean value for biomass (2.00 kg). The graphical presentation of data for biomass is given in Fig. 2.

4.2 Plant analysis

4.2.1 Nitrogen of poplar ETP's leaves as influenced by microbial consortium and clones and in nursery

a) September

Nitrogen of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for nitrogen as affected by biofertilizers application, genotypes and their interactions given in Table 4.5. It was observed that among the different doses of biofertilizers level for shows significant difference with respect to nitrogen.

The data indicated in Table 4.5 showed that there is a significant difference among different doses of biofertilizers levels for nitrogen concentration in leaves. Data depicted that maximum nitrogen concentration was recorded in biofertilizer application at 10 kg/acre having mean value of (1.53%) and which is significantly higher as compared to control with mean value of (1.50%) and biofertilizer application at 6 kg/acre with nitrogen concentration (1.50%).

The data indicated in Table 4.4 revealed that there is a significant difference among different clones for nitrogen concentration in leaves. Among the different clones maximum nitrogen concentration was recorded in clone L-47/88 having value of (1.61%) which is significantly higher than all other clones The order of clones for decrease in nitrogen concentration was L-47/88(1.61%) > L-48/99 (1.56%) > PL-6 (1.55%) > PL-7 (1.52%) > PL-5 (1.51%) > PL-4 (1.51%) > PL-3 (1.47%) > PL-1 (1.43%) > PL-2 (1.40%).

Table 4.5: Nitrogen concentration (%) of poplar ETP's leaves during September 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	1.37	1.45	1.41	1.49	1.43
PL 2	1.44	1.36	1.41	1.45	1.40
PL 3	1.44	1.45	1.53	1.48	1.47
PL 4	1.57	1.52	1.44	1.49	1.51
PL 5	1.47	1.52	1.48	1.58	1.51
PL 6	1.52	1.60	1.55	1.52	1.55
PL 7	1.52	1.50	1.55	1.53	1.52
L-47/88	1.61	1.57	1.61	1.65	1.61
L-48/89	1.52	1.57	1.55	1.60	1.56
Mean	1.50	1.50	1.51	1.53	
Factor	**C.D (0.05)**				
Clone	0.03				
Biofertilizer	0.03				
Clone x Biofertilizer	0.08				

The interaction between biofertilizer and clone is found significant for nitrogen concentration in leaves. Maximum nitrogen concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone L-47/88 with mean value of (1.65%) and minimum nitrogen concentration was recorded in interaction between clone PL-2 and biofertilizer application at 6 kg/acre with mean value of (1.36%). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of nitrogen concentration in leaves of poplar ETP's production in nursery. The graphical presentation of data for nitrogen concentration in leaves is given in Fig. 3.

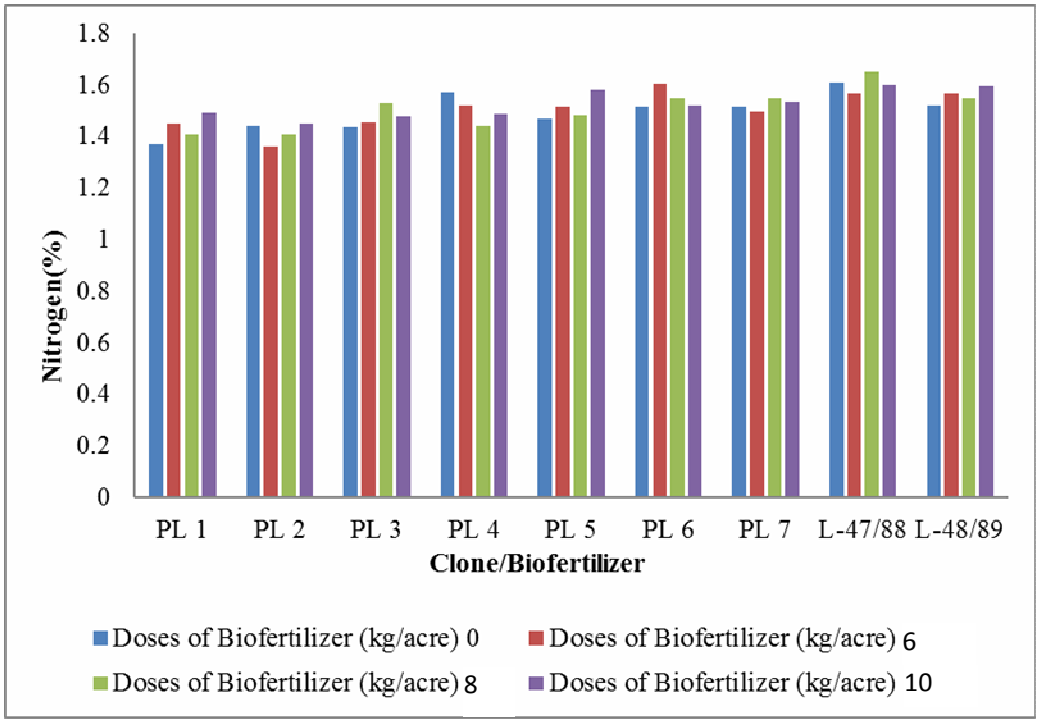

Fig. 3: Graphical representation of nitrogen concentration influenced by treatments during month of September

b) October

Nitrogen of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for nitrogen as affected by biofertilizers application, genotypes and their interactions given in Table 4.6.

It was observed that among the different doses of biofertilizers level for shows significant difference with respect to nitrogen. The data indicated in Table 4.6 showed that there is a significant difference among different doses of biofertilizers levels for nitrogen concentration. Data depicted that maximum nitrogen concentration was recorded in biofertilizer

Table 4.6: Nitrogen concentration (%) of poplar ETP's leaves during October 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	1.43	1.51	1.47	1.55	1.49
PL 2	1.50	1.42	1.47	1.45	1.46
PL 3	1.50	1.57	1.53	1.61	1.55
PL 4	1.56	1.48	1.53	1.51	1.52
PL 5	1.56	1.53	1.63	1.59	1.58
PL 6	1.67	1.62	1.54	1.59	1.61
PL 7	1.57	1.62	1.62	1.72	1.63
L-47/88	1.68	1.76	1.71	1.76	1.70
L-48/89	1.68	1.66	1.71	1.62	1.67
Mean	1.57	1.57	1.58	1.60	
Factor	**C.D (0.05)**				
Clone	0.03				
Biofertilizer	0.03				
Clone x Biofertilizer	0.08				

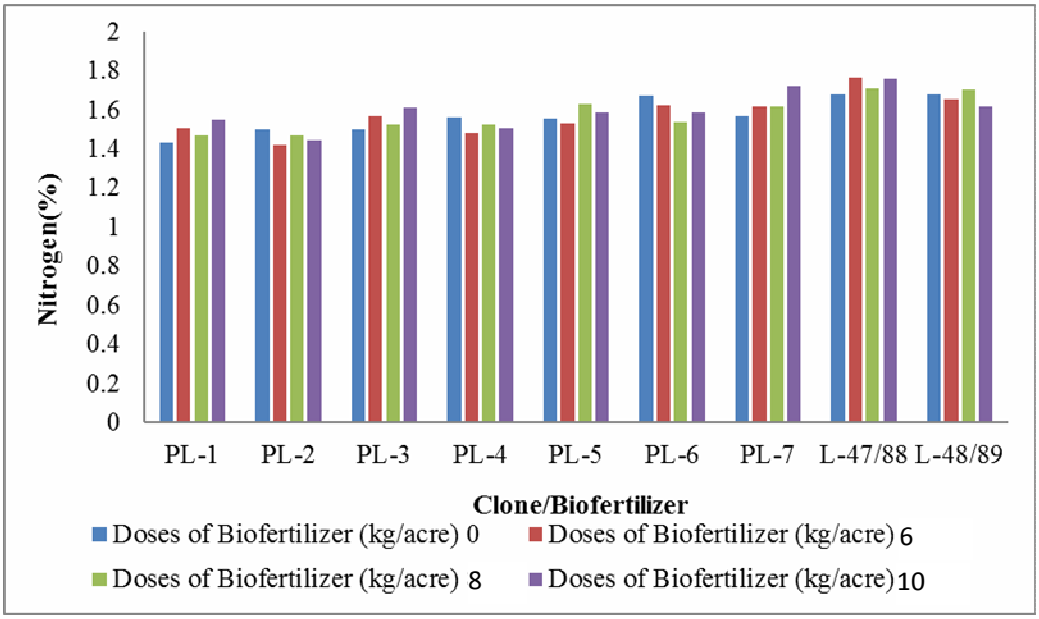

Fig. 4: Graphical representation of Nitrogen in leaves influenced by treatments during month of October

application at 10 kg/acre having mean value of (1.60%) and which is significantly higher as compared to control having nitrogen concentration of (1.57%) and application at 6 kg/acre with a mean value of (1.57%) and is statistically at par with biofertilizer application at 8 kg/acre having mean value of (1.58%).

The data in Table 4.6 revealed that there is a significant differences among different clones for nitrogen concentration in leaves. Among the different clones maximum nitrogen concentration was recorded in l-47/88 having nitrogen concentration of (1.70%) which is significantly higher than clones PL-1 having mean value of (1.49%), PL-2 with a value of (1.46%), PL-3 having nitrogen concentration of (1.55%), PL-4 having mean value of (1.52%), PL-5 having nitrogen concentration of (1.58%), PL-6 with a mean value of (1.61%) and PL-7 having mean value of (1.63 %) and is statistically at par with l-48/89 (1.67%).

The interaction between biofertilizer and clone is found significant for nitrogen concentration among the different interactions Maximum nitrogen concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone L-47/88 having mean value of (1.76%) and minimum nitrogen concentration was recorded in interaction between clone PL-2 biofertilizer application at 6 kg/acre having nitrogen concentration of (1.42%). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of nitrogen concentration in leaves of poplar ETP's production in nursery. The graphical presentation of data for nitrogen concentration is given in Fig.4.

c) November

Nitrogen of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for nitrogen as affected by biofertilizers application, genotypes and their interactions given in Table 4.7.

It was observed that among the different doses of biofertilizers level for shows significant difference with respect to nitrogen. The data indicated in Table 4.7 showed that there is a significant differences among different doses of biofertilizers levels for nitrogen accumulation Data depicted that maximum nitrogen concentration was recorded in biofertilizer application at 10 kg/acre having nitrogen concentration of (1.86%) and which is significantly higher as compared to control with a mean value of (1.70%) and application at 6 kg/acre having a mean value (1.81%) and is statistically at par with biofertilizer application at 8 kg/acre having nitrogen concentration of (1.84%).

The data in Table 4.7 revealed that there is a significant difference among different clones for nitrogen accumulation in leaves. Among the different clones maximum

Table 4.7: Nitrogen concentration (%) of poplar ETP's leaves during November 2015 as influenced by different clones and levels of microbial consortium

Clone	Doses of Biofertilizer (kg/acre)				Mean
	0	6kg	8kg	10kg	
PL 1	1.91	1.89	1.97	2.11	1.95
PL 2	1.56	1.46	1.49	2.14	1.66
PL 3	1.46	1.85	1.79	1.66	1.69
PL 4	1.6	1.81	1.86	1.7	1.74
PL 5	1.01	1.94	1.99	2.11	1.76
PL 6	1.75	1.69	1.76	1.79	1.74
PL 7	1.87	1.75	1.68	1.65	1.73
L-47/88	2.24	1.68	1.7	2.12	1.98
L-48/89	1.83	2.23	2.34	1.49	1.95
Mean	1.70	1.81	1.84	1.86	
Factor	**C.D**				
Clone	0.03				
Biofertilizer	0.03				
Clone x Biofertilizer	0.06				

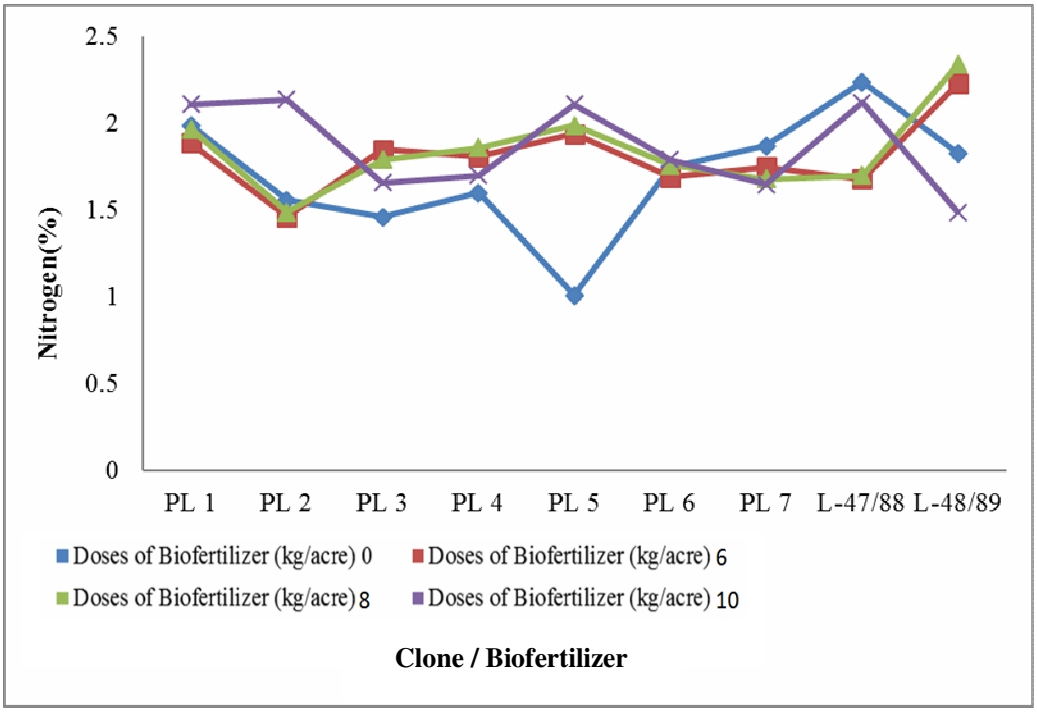

Fig. 5: Graphical representation of Nitrogen influenced by treatments during the month of November

nitrogen accumulation was recorded in clone L-47/88 having nitrogen concentration of (1.98%) which is significantly higher than all other clones.

The interaction between biofertilizer and clone is found significant for nitrogen accumulation among the different interactions maximum nitrogen accumulation was recorded in interaction biofertilizer application rate 8kg/acre and clone L-48/89 having nitrogen concentration of (2.34%) and minimum nitrogen accumulation was recorded in interaction between clone PL-3 and control with a mean value of (1.46%) statistically at par with interaction between clone PL-2 and biofertilizer application at 6 kg/acre having nitrogen concentration of (1.46%). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of nitrogen concentration in leaves of poplar ETP's production in nursery. The significant variation in N concentration due to microbial consortium application in the present study observed, these results are in line with the results by Ravichandran and Balasubramian (2006) reported enhanced N uptake in *Causarina equisetifolia* with dual inoculation, (AM fungi + Frankia). Singh and Puri (2006) also reported enhanced N uptake in *Albizzia lebbek* plants with dual inoculation as compared to that with single and uninoculated control. The graphical presentation of data for nitrogen concentration is given in Fig. 5.

4.2.2 Phosphorus of poplar ETP's leaves as influenced by microbial consortium and clones and in nursery.

a) September

Phosphorus of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for phosphorus as affected by biofertilizers application, genotypes and their interactions given in Table 4.8. It was observed that among the different doses of biofertilizers level for shows significant difference with respect to phosphorus. The data indicated in Table 4.8 showed that there is a significant differences among different doses of biofertilizers levels for phosphorus concentration. Data depicted that maximum phosphorus concentration was recorded in biofertilizer application at 10 kg/acre having phosphorus concentration of (0.292%) and which is significantly higher as compared to control with a mean value of (0.277%) and is statistically at par with biofertilizer application at 6 kg/acre having a mean value (0.281%) and 8kg/acre having phosphorus concentration of (0.283%).

The data in Table 4.8 revealed that there is a significant differences among different clones for phosphorus concentration. Among the different clones maximum phosphorus

Table 4.8: Phosphorus concentration (%) of poplar ETP's leaves during September 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	0.256	0.262	0.265	0.267	0.263
PL 2	0.243	0.258	0.268	0.289	0.257
PL 3	0.266	0.27	0.279	0.287	0.275
PL 4	0.271	0.284	0.277	0.289	0.280
PL 5	0.273	0.287	0.279	0.287	0.282
PL 6	0.292	0.281	0.292	0.286	0.287
PL 7	0.271	0.283	0.294	0.299	0.286
L-47/88	0.299	0.31	0.301	0.314	0.304
L-48/89	0.307	0.294	0.306	0.313	0.305
Mean	0.277	0.281	0.283	0.292	
Factor	**C.D (0.05)**				
Clone	0.013				
Biofertilizer	0.014				
Clone x Biofertilizer	N.S				

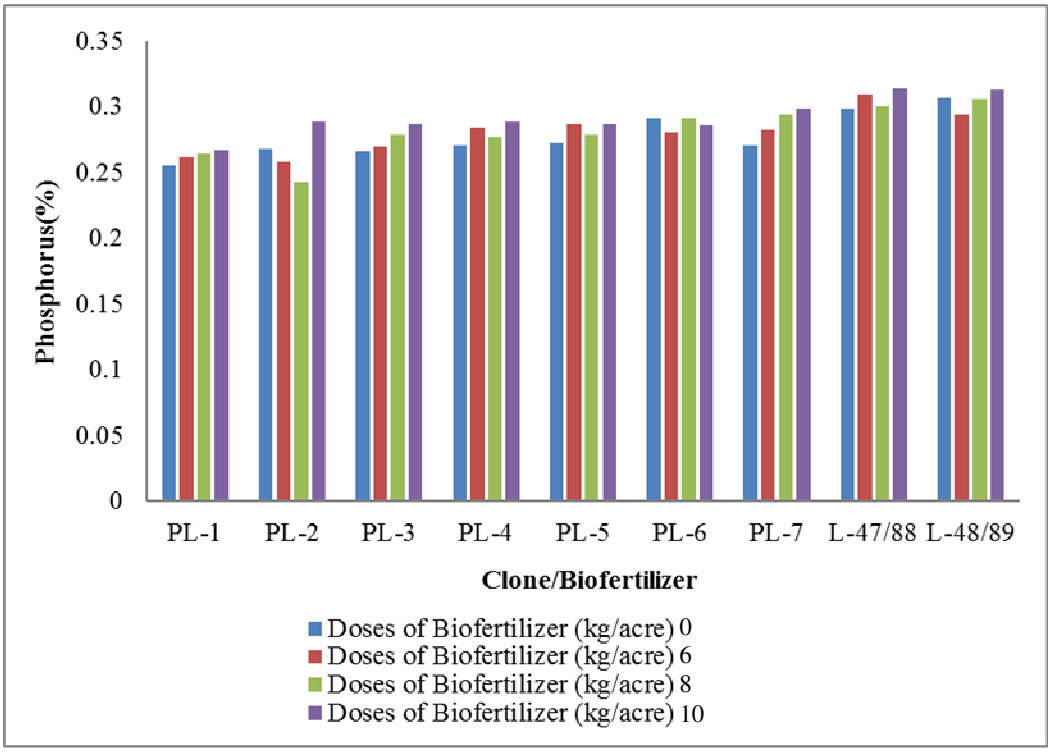

Fig. 6: Graphical representation of phosphorus concentration influenced by treatments during month of September

concentration was recorded in clone L-48/89 having phosphorus concentration of (0.305%) which is significantly higher than clones PL-1 with a mean value of (0.263%), PL-2 having a mean value of (0.257%), PL-3 having phosphorus concentration of (0.0275%), PL-4 with a mean value of (0.280%), PL-5 having a mean value of (0.282%), PL-6 having phosphorus concentration of (0.287%) and PL-7 with a mean value of (0.286%) and is statistically at par with L-47/88 having phosphorus concentration of (0.304%).

The interaction between biofertilizer and clone is found non-significant for phosphorus concentration in leaves. Among the different interactions maximum phosphorus concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone L-47/88 having phosphorus concentration of (0.314%) and minimum phosphorus concentration was recorded in interaction between clone PL-2 and control with a mean value of (0.243%). The graphical presentation of data for phosphorus concentration is given in Fig. 6.

b) October

Phosphorus of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for phosphorus as affected by biofertilizers application, genotypes and their interactions given in Table 4.9. It was observed that among the different doses of biofertilizers level showed significant difference with respect to phosphorus. The data indicated in Table 4.9 showed that there is a significant difference among different doses of biofertilizers levels for phosphorus concentration.

Data depicted that maximum phosphorus concentration was recorded in biofertilizer application at 10 kg/acre having phosphorus concentration of (0.302%) and which is significantly higher as compared to control having mean value of (0.290%) and is statistically at par with biofertilizer application at 6 kg/acre with a mean value of (0.294%) and 8kg/acre having phosphorus concentration of (0.297%).

The data in Table 4.9 revealed that there is a significant difference among different clones for phosphorus concentration in leaves. Among the different clones maximum phosphorus concentration was recorded in clone L-47/88 having phosphorus concentration of (0.327%) which is significantly higher than all other clones PL-1 having mean value of (0.271%), PL-2(0.269%), PL-3 having phosphorus concentration of (0.283%), PL-4 having mean value of (0.287%), PL-5 with a mean value of (0.296%), PL-6 having phosphorus concentration of (0.307%)andPL-7 having mean value of (0.305%) and is statistically at par with L-48/89 having phosphorus concentration of (0.317%).

The interaction between biofertilizer and clone is found non-significant for potassium

Table 4.9: Phosphorus concentration (%) of poplar ETP's leaves during October 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	0.264	0.267	0.271	0.278	0.271
PL 2	0.277	0.271	0.265	0.266	0.269
PL 3	0.274	0.282	0.287	0.289	0.283
PL 4	0.279	0.295	0.286	0.289	0.287
PL 5	0.282	0.292	0.304	0.307	0.296
PL 6	0.307	0.301	0.316	0.305	0.307
PL 7	0.29	0.303	0.304	0.324	0.305
L-47/88	0.326	0.327	0.323	0.334	0.327
L-48/89	0.315	0.312	0.32	0.322	0.317
Mean	0.29	0.294	0.297	0.302	
Factor	**C.D (0.05)**				
Clone	0.012				
Biofertilizer	0.011				
Clone x Biofertilizer	N.S				

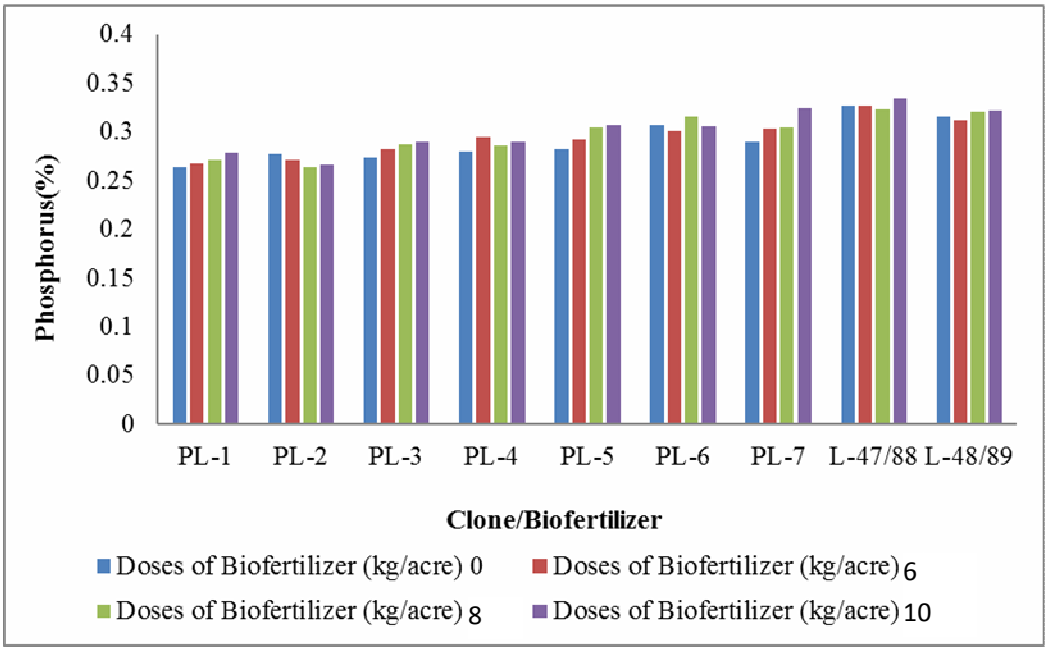

Fig. 7: Graphical representation of phosphorus concentration influenced by treatments during month of October

concentration in leaves. Among the different interactions maximum phosphorus concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone L-47/88 having mean value of (0.334%) and minimum phosphorus concentration was recorded in interaction between clone PL-1 and control with a mean value of (0.264%). The graphical presentation of data for phosphorus concentration is given in Fig. 7.

c) November

Phosphorus of poplar ETP's in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean uptake of plant for phosphorus as affected by biofertilizers application, genotypes and their interactions given in Table 4.10.

The data indicated in Table 4.10 showed that there is a significant difference among different doses of biofertilizers levels for phosphorus concentration. The data indicated in Table 4.10 showed that there is a significant difference among different doses of biofertilizers levels for phosphorus concentration. Data depicted that maximum phosphorus accumulation was recorded in biofertilizer application at 10 kg/acre having phosphorus concentration of (0.317%) and which is significantly higher as compared to control having mean value of (0.303%) and application at 6 kg/acre with a mean value of (0.308%) and is statistically at par with biofertilizer application at 8 kg/acre having phosphorus concentration of (0.314%).

The data in Table 4.10 revealed that there is a significant differences among different clones for phosphorus accumulation in leaves. Among the different clones maximum phosphorus concentration was recorded in clone PL-1 having phosphorus concentration of (0.322%) which is significantly higher than clones PL-2 having mean value of (0.305%), PL-5 having phosphorus concentration of (0.302%), PL-6 with a mean value of (0.305%)andl-48/89 having phosphorus concentration of (0.307%) and statistically at par with clones PL-3 having mean value of (0.312%), PL-4 with a mean value of (0.317%), PL-7 having mean value of (0.315%)and L-47/88 having phosphorus concentration of (0.312%).

The interaction between biofertilizer and clone is found significant for phosphorus accumulation in leaves. Among the different interactions maximum phosphorus accumulation was recorded in interaction biofertilizer application rate 10kg/acre and clone PL-5 having phosphorus concentration of (0.337) and minimum phosphorus accumulation was recorded in interaction between clone L-48/89 and control having mean value of (0.287%). The significant variation in P concentration due to microbial consortium application in the present study observed, these results are in line with the results by Singh and Puri (2006) reported increased phosphorous uptake in the roots of *Dalbergia sissoo* plants with dual inoculation of

Table 4.10: Phosphorus concentration (%) of poplar ETP's leaves during November 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	0.307	0.331	0.320	0.320	0.322
PL 2	0.320	0.290	0.307	0.303	0.305
PL 3	0.300	0.307	0.317	0.320	0.312
PL 4	0.313	0.320	0.320	0.317	0.317
PL 5	0.290	0.290	0.297	0.337	0.302
PL 6	0.300	0.307	0.300	0.310	0.305
PL 7	0.303	0.313	0.333	0.317	0.315
L-47/88	0.300	0.307	0.313	0.320	0.312
L-48/89	0.287	0.300	0.317	0.319	0.307
Mean	0.303	0.308	0.314	0.317	
Factor	**C.D (0.05)**				
Clone	0.012				
Biofertilizer	0.008				
Clone x Biofertilizer	0.024				

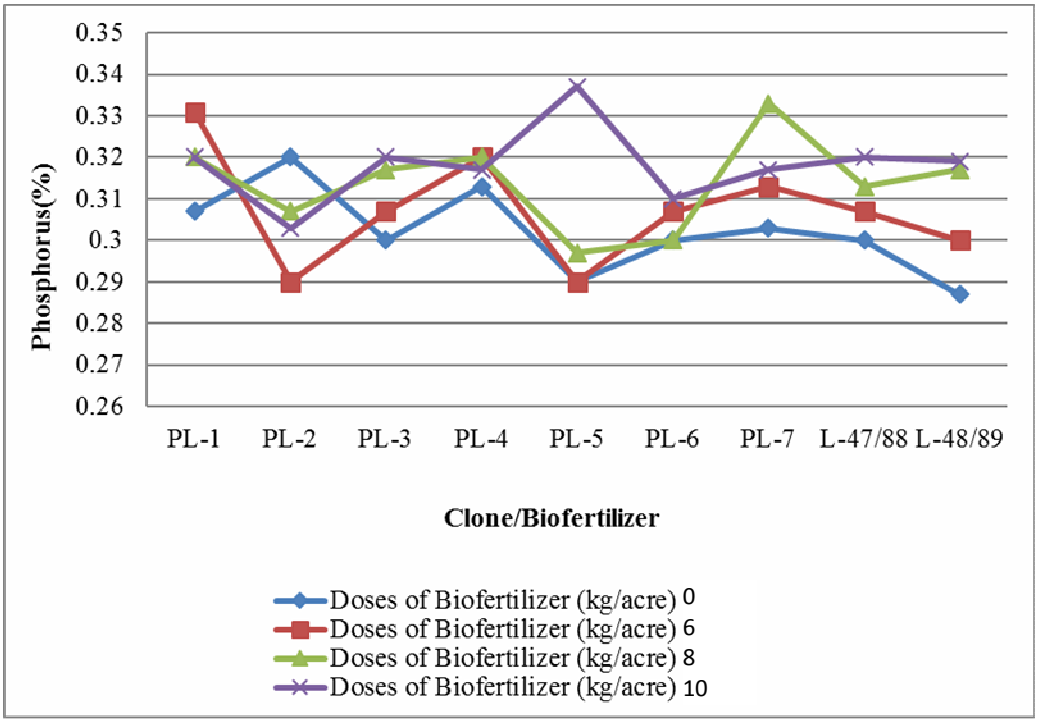

Fig. 8: Graphical representation of phosphorus concentration influenced by treatments during month of November

AM fungi and *Rhizobium.*. Banyal and Bhardwaj (2003) also reported increased P uptake with *Rhizobium* inoculation in *Acacia mollissima*. The graphical presentation of data for phosphorus concentration is given in Fig. 8.

4.2.3 Potassium of poplar ETP's as influenced by microbial consortium and clones and in nursery

a) September

Potassium of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for potassium as affected by biofertilizers application, genotypes and their interactions given in Table 4.11.

It was observed that among the different doses of biofertilizers level for shows significant difference with respect to potassium in leaves. The data indicated in Table 4.11 showed that there is a significant difference among different doses of biofertilizers levels for potassium concentration. Data depicted that maximum potassium concentration was recorded in biofertilizer application at 10 kg/acre having potassium concentration of (0.804%) and which is significantly higher as compared to control having mean value of (0.775%) and application at 6 kg/acre with a mean value of (0.779%) and is statistically at par with biofertilizer application at 8 kg/acre having potassium concentration of (0.782%).

The data in Table 4.11 revealed that there is a significant differences among different clones for potassium concentration in leaves. Among the different clones maximum potassium concentration was recorded in clone L-47/88 having potassium concentration of (0.843%)which is significantly higher than all other clones and the order of clones of decrease in potassium concentration was L-48/89 (0.809%) > PL-6 (0.802%) > PL-7 (0.797%) > PL-5 (0.779%) > PL-4 (0.777%) > PL-. (0.762%) > PL-1 (0.752%) > PL-2 (0.722%).

The interaction between biofertilizer and clone is found significant for potassium concentration in leaves. Among the different interactions maximum potassium concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone PL-7 having potassium concentration of (0.890%) and minimum potassium concentration was recorded in interaction between clone PL-3 and control having mean value of (0.700%). The graphical presentation of data for potassium concentration is given in Fig. 9.

b) October

Potassium of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for potassium as affected by biofertilizers application,

Table 4.11: Potassium concentration (%) of poplar ETP's during September 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	0.79	0.72	0.747	0.75	0.752
PL 2	0.753	0.717	0.701	0.789	0.722
PL 3	0.7	0.82	0.75	0.777	0.762
PL 4	0.78	0.783	0.747	0.798	0.777
PL 5	0.747	0.74	0.85	0.784	0.779
PL 6	0.807	0.81	0.813	0.792	0.802
PL 7	0.76	0.777	0.76	0.89	0.797
L-47/88	0.82	0.847	0.85	0.853	0.843
L-48/89	0.817	0.8	0.817	0.803	0.809
Mean	0.775	0.779	0.782	0.804	
Factor	**C.D (0.05)**				
Clone	0.033				
Biofertilizer	0.025				
Clone x Biofertilizer	0.057				

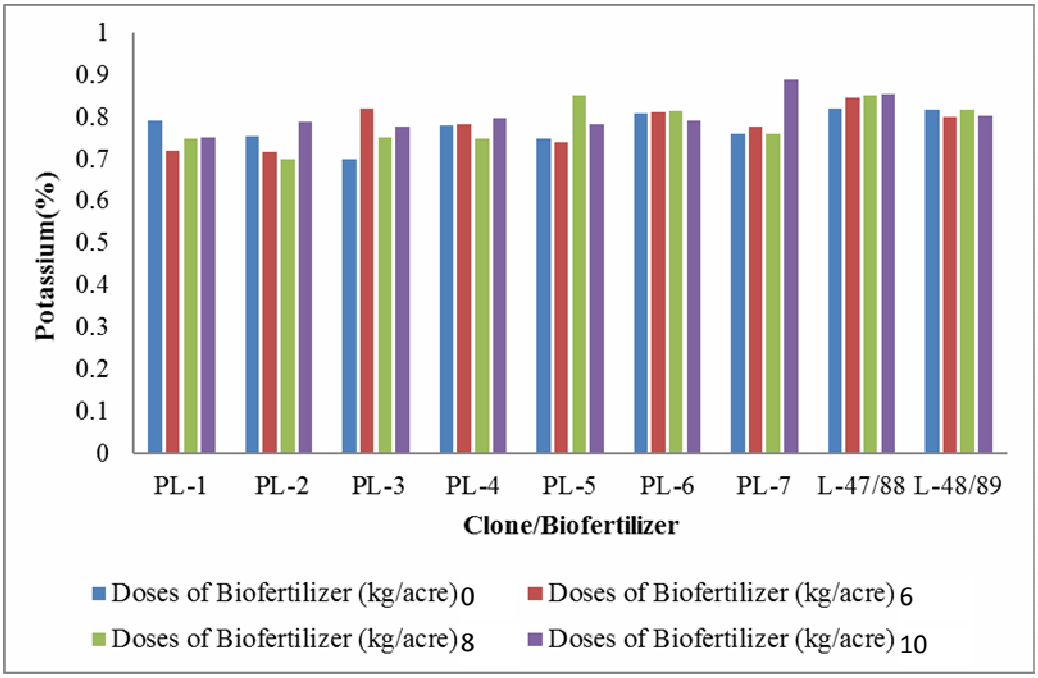

Fig. 9: Graphical representation of potassium concentration influenced by treatments during month of September

genotypes and their interactions given in Table 4.12.

It was observed that among the different doses of biofertilizers level for shows significant difference with respect to potassium in leaves. The data indicated in Table 4.12 showed that there is a significant differences among different doses of biofertilizers levels for potassium concentration. Data depicted that maximum potassium concentration was recorded in biofertilizer application at 10 kg/acre having potassium concentration of (1.096%) and which is significantly higher as compared to control having mean value of (1.058%) and application at 6 kg/acre with a mean value of (1.061%) and is statistically at par with biofertilizer application at 8 kg/acre having potassium concentration of (1.071%).

The data in Table 4.12 revealed that there is a significant differences among different clones for potassium concentration in leaves. Among the different clones maximum potassium concentration was recorded in clone L-48/89 having potassium concentration of (1.161%)which is significantly higher than all other clones PL-1 having mean value of (0.983%), PL-2 with a mean value of(1.011%), PL-3 having potassium concentration of (1.102%), PL-4 having mean value of (1.037%), PL-5 with a mean value of(1.088%), PL-6 having potassium concentration of (1.101%) and PL-7 having mean value of (1.112%), L-47/88 having potassium concentration of (1.114%).

The interaction between biofertilizer and clone is found significant for potassium concentration in leaves. Among the different interactions maximum potassium concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone L-48/89 having potassium concentration of (1.172%) and minimum potassium concentration was recorded in interaction between clone PL-1 and biofertilizer application rate 6kg/acre having mean value of (0.887%). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of potassium concentration in leaves of poplar ETP's production in nursery. The graphical presentation of data for potassium concentration is given in Fig. 10.

c) November

Potassium of poplar ETP's leaves in nursery as influenced by genotypes of poplar and levels of microbial consortium described as below:

Mean performance of plant for potassium as affected by biofertilizers application, genotypes and their interactions given in Table 4.13.

It was observed that among the different doses of biofertilizers level the significant difference with respect to potassium in leaves. The data indicated in Table 4.13 showed that there is a significant difference among different doses of biofertilizers levels for potassium concentration. Among the different biofertilizer rates, maximum potassium concentration was

Table 4.12: Potassium concentration (%) of poplar ETP's leaves during October 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer level (kg/acre)				Mean
	0	6	8	10	
PL 1	0.997	0.887	1.013	1.035	0.983
PL 2	0.97	1.005	0.997	1.068	1.011
PL 3	1.02	1.021	0.937	1.063	1.102
PL 4	1.027	1.02	1.053	1.047	1.037
PL 5	1.09	1.07	1.107	1.085	1.088
PL 6	1.123	1.087	1.08	1.113	1.101
PL 7	1.107	1.15	1.13	1.147	1.112
L-47/88	1.037	1.163	1.127	1.13	1.114
L-48/89	1.153	1.147	1.19	1.172	1.161
Mean	1.058	1.061	1.071	1.096	
Factor	**C.D (0.05)**				
Clone	0.042				
Biofertilizer	0.035				
Clone x Biofertilizer	0.031				

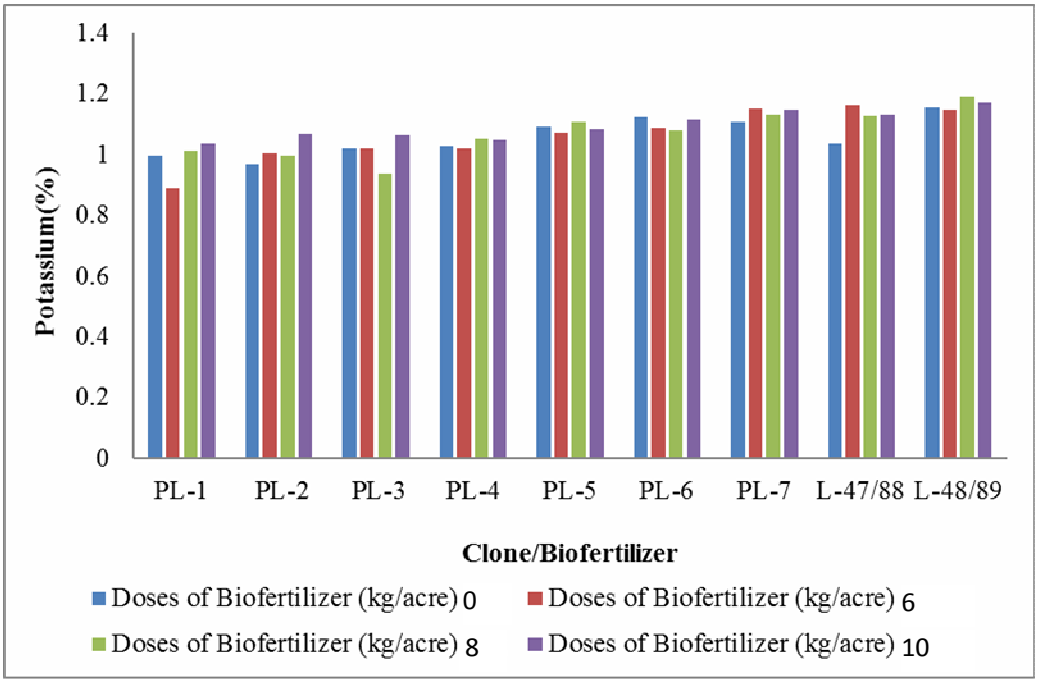

Fig. 10: Graphical representation of potassium concentration influenced by treatments during month of October

Table 4.13: Potassium concentration (%) of poplar ETP's leaves during November 2015 as influenced by different clones and levels of microbial consortium

Clone	Biofertilizer levels (kg/acre)				Mean
	0	6	8	10	
PL 1	1.28	1.34	1.44	1.67	1.43
PL 2	1.53	1.53	1.83	1.67	1.65
PL 3	1.32	1.49	1.69	1.39	1.43
PL 4	1.50	1.50	1.30	1.70	1.50
PL 5	1.62	1.62	1.26	1.53	1.50
PL 6	1.49	1.49	1.64	1.84	1.62
PL 7	1.56	1.56	1.43	1.73	1.57
L-47/88	1.25	1.28	1.76	1.45	1.42
L-48/89	1.41	1.41	1.42	1.61	1.46
Mean	1.44	1.47	1.55	1.60	
Factor	**C.D (0.05)**				
Clone	0.022				
Biofertilizer	0.016				
Clone x Biofertilizer	0.045				

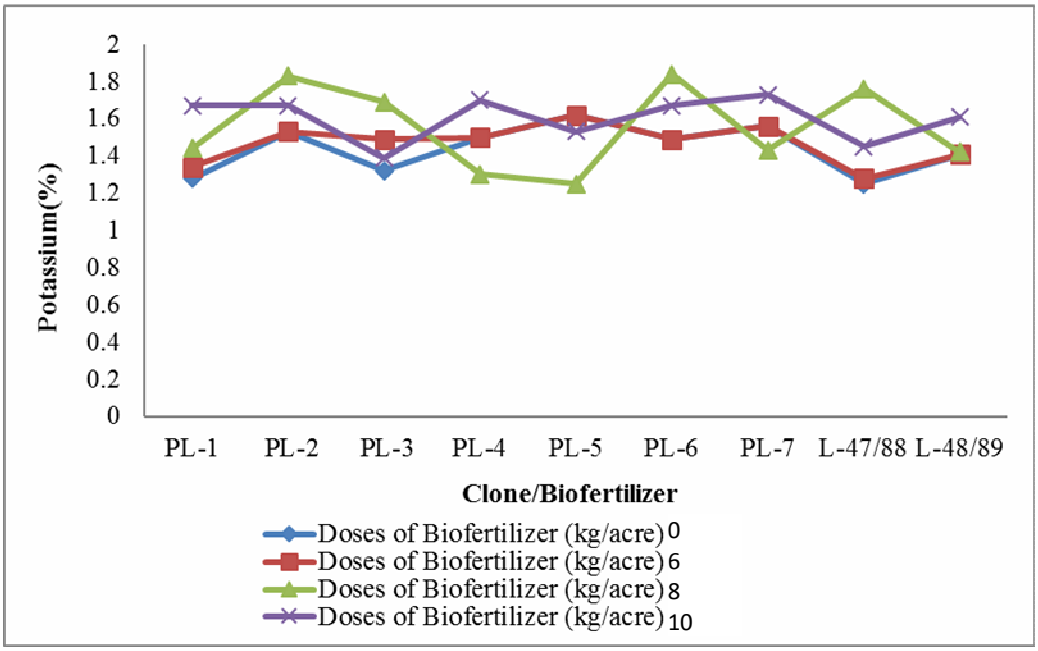

Fig. 11: Graphical representation of potassium concentration influenced by treatments during month of November

reported with application of 10 Kg/acre (1.60%) which is significantly higher as compared to control (1.44%) and all other treatments

The data in Table 4.13. revealed that there is a significant differences among different clones for potassium in leaves. Among the different clones maximum potassium concentration was recorded in clone PL-2 (1.65%) which is significantly higher as compared to all other clones and the order of clones for decrease in potassium concentration was PL-6 (1.62%) > PL-7 (1.57%) > PL-4 (1.50%) = PL-5 (1.50%) > L48/89 (1.46%) > PL-3 (1.43%) = PL-1 (1.43%) > L-47/88 (1.42%)

The interaction between biofertilizer and clone is found significant for potassium concentration in leaves. Among the different interactions maximum potassium concentration was recorded in interaction biofertilizer application rate 10kg/acre and clone PL-6 having potassium concentration of (1.84%) and minimum potassium concentration was recorded in interaction between clone PL-47/88 and biofertilizer application rate 0kg/acre having mean value of (1.25%). The significant interaction between biofertilizer and clones revealed that in different doses of biofertilizer, different clones has differential response for growth in terms of potassium concentration in leaves of poplar ETP's production in nursery. The graphical presentation of data for potassium concentration in leaves is given in Fig. 11.

CHAPTER V

SUMMARY

Poplar as a multi-use species has been introduced as a promises tree for plantation to fulfill the demand and supply of wood. However, due to faster growth rates, more susceptibility to disease, simple breeding methods and inappropriate genetic resources management of the clones that were developed are not able produce a quality nursery stock without affecting the soil health.. Therefore, it is important to study the morphological characteristics and nutrient analysis of poplar clones for raising superior nursery stock through the use of biofertilizers. Plants have also been shown to respond to exogenous application of microbial consortium.

The present study entitled " Study on performance of poplar clones in relation to microbial consortium application in nursery" was conducted in research area of Department of Forestry & Natural Resources at Punjab Agricultural University, Ludhiana during the year 2014-2015 in two factor factorial design with three replications with a objective to study the effect of microbial consortium (biofertlizer Levels 4) on growth of recommended poplar clones (9) in nursery and to study the effect of microbial consortium on the nutrient uptake by recommended poplar clones in nursery

The planting of cuttings of nine poplar clones PL-1, PL-2, PL-3, PL-4, PL-5, PL-6, PL-7, L-47-88 and L-48/89 were carried out at second fortnight of February, 2015 in the nursery. After 40 ± 2 days of planting of the cuttings, application of microbial consortium with treatment of 0kg/acre (control), 6kg/acre, 8kg/acre and 10kg/acre were done. The results of the present investigation are briefly summarized and concluded as under.

Collar diameter of the poplar clones under study differed significantly with respect to the different clones recorded during November 2015. PL-7 had maximum collar diameter The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on collar diameter of poplar showed a significant difference with treatment 10 kg/acre having maximum effect. It was observed that interaction effect between microbial consortium treatments and clone was found significant with respect to collar diameter.

Height of the poplar under study differed significantly with respect to the different clones recorded under study. PL-1 attained maximum height. The effect varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on collar diameter of Poplar shows a significant difference with treatment 10 kg/acre having maximum effect The interaction between clones and microbial were found to significant with respect to plant height.

Clone PL-5 recorded a maximum leaf area The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on leaf area of poplar shows a significant difference with treatment 10 kg/acre having maximum effect with respect to leaf area. It was observed that interaction effect between microbial consortium treatments and clone was found significant with respect to leaf area.

Clone L-48/89 recorded a maximum biomass accumulation The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on biomass accumulation of Poplar shows a significant difference with treatment 10 kg/acre having maximum effect with respect to leaf area. It was observed that interaction effect between microbial consortium treatments and clone was found significant with respect to biomass accumulation in poplar plants.

The significant variation in relation to concentration of leaf Nitrogen in poplar due to clones in the month of September, October and November was observed. Maximum values of leaf N concentration in poplar grown were recorded in the month of November in clone L-47/88. The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on concentration of nitrogen leaves of Poplar shows a significant difference with treatment 10 kg/acre having maximum affect with respect to nitrogen concentration in the month of September, October and November. It was observed that interaction effect between microbial consortium treatments and clone was found significant with respect to nitrogen concentration in September, October and November.

The significant variation in relation to concentration of leaf phosphorus in poplar due to clones in the month of September, October and November was observed. Maximum values of leaf P concentration in poplar grown were recorded in the month of November in clone PL-1. The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial consortium on concentration of phosphorus leaves of Poplar shows a significant difference with treatment 10 kg/acre having maximum effect with respect to phosphorus concentration in the month of September, October and November. It was observed that interaction effect between microbial consortium treatments and clone was found non-significant with respect to phosphorus concentration in month of September and October and found significant in November.

The significant variation in relation to concentration of leaf potassium in poplar due to clones in the month of September, October and November was observed. Maximum value for P concentration in leaf was recorded in the month of November in clone PL-2 of poplar. The effect of varied concentrations (0kg/acre, 6kg/acre, 8kg/acre and 10kg/acre) of microbial

consortium on concentration of phosphorus leaves of Poplar shows a significant difference with treatment 10 kg/acre having maximum effect with respect to phosphorus concentration in the month of September, October and November. It was observed that interaction effect between microbial consortium treatments and clone was found significant with respect to phosphorus concentration in month of September and October and November.

CONCLUSION

The present investigations concluded that application of biofertilizers (6 to 10 kg/acre) significantly increase the nutrient uptake in *Populus deltoides* plants and thereby helped in enhanced growth in nursery.

REFERENCES

Abbott L K and Robson A D (1991) Field management of VA mycorrhizal fungi. In: Keister D L and Cregan P B (Eds.) The rhizosphere and plant growth. Volume 14 of the series Beltsville Symposia in Agricultural Research, pp 355-62. Kluwer Acadmic Publisher.

Agrawal D C, Rawat S K and Bhatnagar H P (1983) Effect of N, P, K fertilizer application on growth of *Pinus caribaea* seedlings. *Indian Forester* **109** (6): 349-56.

Aguiar R L F de, Maria L C, Salcedo I H and Samparo E V de S B (2004) Interaction between arbuscular mycorrhizal fungi and phosphorus on growth of *Prosopis juliflora* (SW) DC. *Revista Arvore* **28** (4): 589-98.

Allen E K and Allen O N (1981) The leguminosae. pp 812. University of Wisconsin Press.

Amalraj ELD, Maiyappan S and Peter AJ (2012) In vivo and in vitro studies of Bacillus megaterium var. phosphaticum on nutrient mobilization, antagonism and plant growth promoting traits. *J Ecobiotechnology* **4** (1):35-42

Anonymous (2010) Package of practices for forest trees, Punjab Agricultural University, Ludhiana printing press, pp.11.

Anonymous (2015) *Basic land uses statistics of Punjab*. Agricultural Hand Book, Punjab Agricultural University, Ludhiana.

Arinaz V, Rayhaneh Amooaghaie, and Mahmoud Otroshy (2014) Effects of plant-growth-promoting rhizobacteria and arbuscular mycorrhizal fungus on plant growth, stevioside, NPK, and chlorophyll content of *Stevia rebaudiana. J Plant Interactions* **9**:128-36.

Aryal V K, Hossain M K, Mridha M A U, Xu H L and Umemurati (1999) Effect of *Rhizobium* inoculation on growth and nodulation of *Albizia procera, Albizia lebbek* and *Leucaena leucocephala. Pedosphere* **9** (2): 153-59 (Original not seen. Abstr in CAB Abstracts: Entry No. 19991908306).

Aseri G K and Rao A V (2005) Interaction of bio-inoculants and chemical fertilizers on biomass production, rhizosphere activity and nutrient uptake of ber (*Zizyphus mauritiana*) var. Rotundiflora LAM. *Ind J For* **28** (4): 401-05.

Awodola A M (1993) Nursery operations in semi arid North of Nigeria: The Sokoto experience. In: (Puri S and Khosla P K Eds.) Nursery technology for agroforestry: Application in arid and semi arid regions. Winrock-oxford and IBH series pp 29-33.

Backiyavathy M R, Arulmozhiselvan K and Perumal R (2005) Effect of nitrogenous fertilizes, *rhizobium* and arbuscular mycorrhizal fungi on nodulation and biomass yield in *Acacia nilotica* (L.) Del and *Acacia planiforous* (L.) under degraded wasteland. *Adv P1 Sci* **18**: 91-97.

Bagyaraj D J (1984) Biological interactions with VA mycorrhizal fungi. In VA mycorrhiza (C L, Powell and D J Bagyaraj, eds.). CRC Press, Boca Raton. USA. pp. 131- 53

Balaji S and Rangarajan M (1988) Growth and noduation of *Acacia nilotica* inoculaton with three r*hizohial* strains. *NFTRR* **6**: 38-39.

Banerjee S K, Kashyap M K, Manjhi R B, Dugaya and Bhowmik A K (1998) Response of fertilizers on growth biomass production and nutrient uptake in *Dalbergia sissoo* grown in iron mine over burden. *Adv For Research India* **19**: 98-118.

Banyal R and Bhardwaj S D (2003) Effect of *Rhizobium* inoculation on growth, biomass and nutrient dynamics of *Acacia catechu* and *Acacia mollissimia* seedlings. *J Tree Sci* **22** (1&2): 28-33.

Banyal R, Bhardwaj S D and Gupta S K (1999) Effect of nitrogen and phosphorus application on growth and nutrient dynamics of *Acacia catechu*. *J Tree Sci* **18** (1&2): 41-46.

Baravkar A A, Kale R N, Patil R N, Sawant S D (2008). Pharmaceutical and biological evaluation of formulated cream of methanolic extract of *Acacia nilotica* leaves. *Res J Pharm Techn* **1**(4): 481-83

Basavaraju V (1986) Nodulation and nitrogen fixation in subabul (*Leucaena leucoceplicila*) (Lam.) do wit. *Mysore J Agric Sci* **20** (4): 347.

Basu P K and Kabi M C (1987) Effect of application of biofertilizers on the growth and nodulation of seven forest legumes. *Indian Forester* **113**: 249-57.

Beijerinck M W (1888) Die bacgterien der Papillion ceenkroll chen. *Bot Zig* **46**: 726-41

Ben Rebah F, Prevost D and Tyagi R D (2002) Growth of alfalfa in sludge-amended soils and inoculated with *rhizobia* produced in sludge. *J Environ Qual* **31**: 1339–48.

Bhardwaj S D, Shamet G S and Masoodi T H (1996) Studies on the effect of spacing and nitrogen fertilization on growth of *Acer oblongum* seedlings in the nursery. *Indian J For* **19** (2): 145-47.

Bhatt M N, Jeyarajan R and Ramaraj B (1993) Response of six forest tree species to inoculation with vesicular arbuscular mycorrhizal. *J Tree Sci* **12** (2): 77-81.

Bhattacharjee R and Dey Utpal (2014) An overview of fungal and bacterial biopesticides to control plant pathogens/diseases. *African J Microbiology Res* **8** (17):1749-62.

Bheemaiah G (2004) Effect of irrigation and fertilizer application on growth of teak (*Teatona grandis*) in semi arid regions. *Indian Forester* **130**: 1311-15.

Bhuiyan M Z A. Hossain M K and Osman K T (2000) Effect of inorganic fertilizers on the initial growth performance of *Casuarina equisetifolia* seedlings in the nursery. *Indian J For* **23**(2): 296-300.

Blatchford N (1978) Nursery practice. In: *Forestry practice. Forestry Commission Bulletin No. N. 14* Her Majesty's Stationary Office, London, pp 5.

Bohra S and Vyas A (2012) Effect of AM fungi on biomass production and nutrient uptake of agroforestry tree seedling of *Acacia* species. *J Bot* **1**: 22-28.

Bora I P. liaruah A and Singh J (2006) Effect of *Rhizohium* inoculation and nitrogen fertilizer application on seeding growth of *Albizia procera* (Roxb.) Benth. *Indian Forester* **132**: 868-77.

Cao D ang Y Ci, Oin S M, Hou Y R, Brundett M, Dell B, Malajczuk N (ed) and Gong M Q (1995) *Mycorrhizas for plantation forestry in Asia. Proc of an international symposium and workshop,* Kaiping, Guang dung Province, P R China, 7-11 November 1994-1995, 119-121; ACIAR Proceedings No. 62.

Chauhan Y S, Pokhriyal T C (2002) Nodulation and nitrogen fixation as influenced by *Rhizobium* and Mycorrhizal inoculation in *Albizia lebbek* (L.) Benth. *Annals For* **10** (2): 243-51.

Chaves L-de-F-de-C, Borges R-de-CG, Neves J C L and Ragazzi A J (1995) Growth of Jacaranda-da-Bahia (*Dalbergia nigra*) seedlings in response to inoculation with vesicular-arbuscular mycorrhizal fungi at different soil phosphorus levels. *Revista-Arvore* **19** (1): 32-49

Chugh R, Kaushik J C and Sharma S (2006) Response of inoculation of different vesicular arbuscular mycorrhizal fungi on *Populus deltoides*. *Indian J For* **29**(2): 157-59.

Colonna J P, Theoen D, Ducousso M and Badji S (1991) Comparative effects of *Glomus mosseae* and P fertilizer on foliar mineral composition of *Acacia senegal* seedlings inoculated with *Rhizobium. Mycorrhiza News* **1**(1): 35-38

Daniel O, Vitorino A C T, Alovisi A A, Mazzochin L, Tokura A M, Pinheiro F R and De-Souza E F (1997) Phosphorus application to *Acacia mangium* WILLI. seedlings, *Revista-Arvore* **21**(2): 163-68.

Deol G S and Khosla P K (1983) Provenance related growth response of *Populus ciliata* Wall Ex Royle to nitrogen fertilization. *Indian Forester* **109**: 33-40.

Dixit R K, Thomas M B, Farooqui M, Patra A K and Spurway M I (1999) Phosphorus response and toxicity in *Acacia spp*. *Indian Forester*. **125**(8): 770- 74.

Dubey R C, Ginwal H S and Sati S C (1997) Prospects of mycorrhizal the Himalaya: forms, function and management. *Himalayan Microbial Diversity* **2**: 317-38.

Dugaya D, Williams A J, Chandra K K, Gupta B N and Banerjee S K (1996) Mycorrhizal development and plant growth in amended coalmine overburden. *Indian J For* **19**(3): 222-26.

Dwivedi A P (1993) Babul (*Acacia nilotica*): a multipurpose tree of dry areas. Arid Forest Research Institute, ICFRE, Jodhpur, India

Gangoo S A, Mughal A H and Makaya A S (1997) Fertilizer response by two species of poplars on initial growth parameters. *Indian Forester* **123**: 240-44.

Garg V K (2000) Response of container, spacing and P fertilizer on growth and quality of *Prosopis juliflora* (Swartz) DC seedlings grown in sodic soils. *Indian J For* **23**(1): 118-22.

Gaur A and Adholeya A (1994) Estimation of VAMF spore in soil: a modified method. *Mycorrhiza News* **6**(1): 10-11.

Gautam S P and Maitra A (1998) Role of VAMF in establishment of *Dendrocalamus strictus* in field. *Indian Forester* **124**: 141-44.

Giri B, Kapoor R, Mukerji K. G (2005) Effect of the arbuscular mycorrhizae *Glomus fasciculatum* and *G. macrocarpum* on the growth and nutrient content of *Cassia siamea* in a semi-arid Indian wasteland soil. *New Forests* **29**:63–73.

Glick BR, Todorovic B, Czarny J, Cheng Z, Duan J and McConkey B (2007). Promotion of plant growth by bacterial ACC deaminase. *Critical Reviews Plant Sci* ***26*** (5-6):227-42.

Gomez K A and Gomez A A (1984) *Statistical procedures for agricultural research* (2nd ed.). John Wiley and Sons Inc., New York pp 680.

Gupta N and Rahangdale R (1999) Response of *Albizia lebbek* and *Dalbergia sissoo* towards dual inculcation of *Rhizobium* and arbuscular mycorrhizal fungi. *Indian J Exp Biology* **37**(1): 1005-11.

Gurumurthy S B and Sreenivasa M (1999) Effect of inoculation of efficient VAM fungus at different levels of P on nutrition and growth of silver oak (*Grevillea robusta*). *Adv For Res India* **21**: 262-71.

Gurumurthy S B, Sreenivasa M N, Kulkarni J H and Nadagoudar B S (1999) Screening and selection of an efficient VAM fungus for shisham (*Dalbergia sissoo*). *Karnataka J Agri Sci* **12**(1 &4): 88-92.

Hayat R, Ali S, Amara U, Khalid R and Ahmed I (2010) Soil beneficial bacteria and their role in plant growth promotion: a review. *Annals Microbiology* **60** (4): 579-98.

Jackson M L (1967) *Soil Chemical Analysis*. Asia Publishing House, Bombay, New Delhi.

Jain A, Singh A, Singh S and Singh HB (2013) Microbial consortium-induced changes in oxidative stress markers in pea plants challenged with Sclerotinia sclerotiorum. *J Plant Growth Regulation* **32** (2): 388-98.

Jakobsen I, Joiner E J and Larsen J (1994) I lyphal-phosphorus transport, a keystone to mycorrhizal enhancement of plant growth. In: (Gianinazzi S and Schnepp H, Eds.) *Impact of arbuscular mycorrhizae on sustainable agriculture and natural ecosystems.* Birkhauser Verlag, Switzerland, pp 133-46.

Jakobsen M L (l 973) *Soil Chemical Analysis*. Prentice Hall, New Delhi (India).

Jamaluddin, Dadwal V S and Chouhan J S (1995) Efficacy of different *Rhizobium* strains of forest trees species on *Albizia lebbek. Indan Forester* **121**(7): 647-50.

Jamaluddin, Dadwal V S and Gosewami M K (2004) Effect of different microorganisms and inorganic fertilizers on seedling growth of *Albizia procera*. *Mycorrhiza News* **16** : 14-16.

Kalavathi B P, Santhana K P and Divya M P (2000) Effect of VA-mycorrhizal fungus and phosphorus solubilzing bacterium in neem. *Indian Forester* **126** (1): 67-70.

Kang L H nad Li S C (1998) Responses of *Acacia* to rhizobia inoculation. *For Res* **11**(4): 343-49

Kaur A and Kumar R (2011) Interaction effect of inorganic and biofertilizer on growth and nutrient uptake in *Dalbergia sissoo* seedlings. *Indian J For* **34** (4): 397-02

Kaur A, Kumar R, Gosal S K (2012) Influence of VAM and *Rhizobium* inoculation at different level of nitrogen and phosphorus on seedling growth in *Dalbergia sissoo. Indian J For* **35** (3): 259-00.

Kaushal R (1996*) Studies on natural nodulation in various leguminous trees and influence of dual (Rhizobium and VAM) fungi inoculation on growth of Albizia lebbek*. Ph.D. Dissertation, University of Horticulture and Forestry, Nauni-Solan (HP), India

Kaushik J C and Kaushik N (1995) Interaction between VAM and *Rhizobium* and their influence on *Albizia lebbek*. In: Adoleya A and Singh S (eds) *Mycorrhizae Biofertilizer for the future*. Pp.52-55, TERI, New Delhi.

Kaushik J C, Dabas P and Kumar R (2003) Influence of *Glomus mosseae*, phosphorus and drought stress on the nodulation and nutrient content of *Acacia nilotica* and *Dalbergia sissoo* seedlings. *Indian Forester* **26**(1): 11- 13.

Khalid A, Arshad M and Zahir Z A (2004) Screening plant growth ‐ promoting rhizobacteria for improving growth and yield of wheat. *J Applied Microbiology* **96** (3): 473-80.

Khan S N and Uniyal K (1999) Growth response of two forest tree species to VAM and *Rhizobium* inoculation. *Indian For* **125** (11): 1125-28.

Khan S N, Uniyal K and Parade Y R (2001) Growth response of *Dalbergia sissoo* to AM and *Rhizobium* inoculations and fertilization in nursery. *Indian Forester* **127**: 906-09,

Klivetong M (1996) Growth response of leguminous tree to *Rhizobium* inoculation and seedlings to EM solutions. *Technical-Publications-ASEAN-Forest-Tree-Seed-Centre-Project* 1996, No. 34, pp ii + 9.

Koffa S N and Cruz R E de La (1995) Screen house performance of VAM- inoculated seedlings of *Leucaena leucocephala* (Lam.) De Wit. in phosphorous deficient and aluminium sulfate treated medium. *New Forests* **9** (3): 273-79.

Krishan G, Bhandari A R and Tripathi D (2000) Effect of dual (Rhizobium + AM) inoculation of the seedlings of *Albizia kbbek* under glasshouse conditions. *Indian Forester* **132**: 1047-52.

Kumar A, Dash and Jhariyan M K (2013) Impact of *Rhizobium* on growth, biomass accumulation and nodulation in *Dalbergia sissoo* seedling. *The bioscan* **8**(2): 553-60.

Kumar J and Siddiqui M H (2004) Increased biomass production of *Albizia lebbek* (L.) Benth in nursery by the use of inorganic fertilizers. *Indian J For* **27** (4): 360-66.

Kumar R (2006) Effect of doses and method of phosphorus application on growth of *Populus deltoides* under nursery condition. *Indian J For* **29** (3): 267-69.

Kumudha P (2005) Studies on the effect of biofertilizers on the germination of *Acacia nilotica* Linn. seeds. *Adv Pl Sci* **18**(2): 679-84.

Lakshmipathy R, Gowda B, Chandrika K and Bagyaraj D J (2003) Symbiotic response of *Garcinia indica* (Roxb.) Jessop to VA mycorrhizal inoculation. *Indian J For* **26** (2): 143-46.

Lipton DS, Blanchar RW and Blevins DG (1987). Citrate, malate, and succinate concentration in exudates from P-sufficient and P-stressed Medicago sativa L. seedlings. *Plant Physiology* 85 (2), 315-17.

Mahajan A, Chodhary A K, Jaggi R C and Dogra R K (2003) Importance of biofertilizers in sustainable agriculture. Farmers Forum,: 17-19.

Mandal B S and Kaushik J C (1995) Interaction between VA mycorrhizae fungi and *Rhizobium* and their effect on the growth parameters of *Acacia nilotica* (L.) WILLD EX DEL. *Haryana Agri Univ J. Res.* **25**: 107- 11

Manjunath A, Bagyaraj D J and Gowda H (1984) Dual inoculation with VA mycorrhizae and *Rhizobium* is beneficial to *Leucaena*. *Plant Soil* **78**: 445-48.

Manoharachary C and Reddy P J (1995) Role of vesicular arbuscualr mycorrhizal fungi in forestry. *Proceedings of 3rd National Conference on Mycorrhizae.* TERI, New Delhi, pp. 534-40

McGill WB and Cole CV (1981) Comparative aspects of cycling of organic C, N, S and P through soil organic matter. *Geoderma* **26** (4): 267-86.

McGraw A C and Handrix J W (1984) Host and soil fumigation effects on spore population densities of species of endogonaceous mycorrhizal fungi. *Mycologia* **76**: 122-31.

Megala S and Elango R (2012) In vitro antibacterial activity studies of tuber and seed extracts of gloriosa superba linn. Against some selected human pathogen. *International J Pharmaceutical Sci Res* **3** (10): 4230-34

Mehrotra M D (1995) A practical approach to mycorrhizae containerized seedlings in forest nurseries. *Indian Forester* **121**: 670-77.

Mehrotra M D (1997) Fanatastic growth response of *Paulownia* to mycorrhization and fertilization. *Indian Forester* **123**: 873-75.

Mehrotra M D, Khan S N and Uniyal K (1999) Study on the impact of mycorrhiza and fertilizer on the growth of bamboo. *Indian J For* **6** (3&4): 118-23.

Mehrotra V S (1996) Use of revegetated coal mine spoil as source of arbuscular mycorrhizal inoculum for nursery inoculations. *Curr Sci* **71**(11): 73-77.

Mehta P, Rana B S and Verma S K (2012) Effect of nitrogen and phosphorus fertilizers on seedling growth and biomass of teak (*Tectona grandis*) on sodic soil. *Indian Forester* **138** (7): 624-27.

Merwin M D and Peech M (1950) Exchangeability of soil potassium in sand, silt and clay fractions as influenced by the nature of the complimentary exchangeable cations. *Soil Sci Soc Am Proc* **15**: 125-28.

Michelsen A and Rosendahl S (1990) The effects of VA mycorrhizal fungi, phosphorus and drought stress on the growth of *Acacia nilotica* and *Leucaena leucocephala* seedlings. *Plant Soil* **124** (1): 7-13.

Miller D D, Domoto P A and Walker C (1985) Colonization and efficiency of different endomycorrhizal fungi with apple seedlings at two phosphorus levels. *New Phytol* **100**: 393- 02.

Mishra V K and Chauhan S K (1997) Response of N and P fertilizers on *Ulmus villosa* seedlings morphological indices and fertilizer response function. *Indian J For* **20** (1): 74-77.

Mohan S (1992) Fertilizer response on the growth and biomass of a common timber species of Arunachal Pradesh Terminal myriocarpa (Hollock) seedlings. *Indian Forester* **118**: 822-31.

Nadeem SM, Zahir ZA, Naveed M and Ashraf M (2010) Microbial ACC-deaminase: prospects and applications for inducing salt tolerance in plants. *Critical reviews in plant sci* **29** (6): 360-93.

Nagaveni H C and Vijaylakshmi G (2002) Effect of VAM and *Azotobacter* inoculation on growth and biomass production in forestry species. *Indian J For* **25** (3): 286-90.

Nema S, Behari B and Jamaluddin (1998) Effect of VAM on growth and development of bamboo planted under agroforestry system. *Indian Forester* **124**: 516-23.

Niranjan R, Mohan V, Rao V M (2007) Effect of Indole Acetic Acid on the synergistic interactions of *Bradyrhizobium* and *Glomus fasciculatum* on growth, nodulation, and nitrogen fixation of *Dalbergia sissoo* Roxb. *Arid Land Research and Management* **21:** 329-42

Niranjan R, Sharma P, Banwari L, Rao V M, Sharma P, Jalai B L and Chand H (eds.) (1990) *Trends in mycorrhizal research. Proc of the National Conference on Mycorrhiza*, Haryana Agricultural University, Hisar, India, Feb 14-16: 205-07.

Niranjan R, Shukla R, Pareek R and Rao V M (2002) Dual inoculation effect of *Rhizobium* (Lewpea miscellary) and VAM fungi on growth, nodulation and nitrogen fixation in *Prosopis cineraria*. *J Phytological Research* **15**(2): 149-53.

Olsen S R, Cole C V. Watanabe F S and Dean L A (1954) *Estimation of available phosphorus in soil by extraction with sodium bicarbonate*. US Department Agri. Circ. p 239, Washington DC.

Panse VG and Sukhatme PV (1989) Statistical Methods for Agricultural Workers. *Indian Council Agriculture Research*, New Delhi pp. 359

Parkash V, Aggarwal A, Sharma S and Sharma D (2005) Effect of endophytic and fungal bioagent on the development and growth of *Eucalyptus saligna* seedlings. *Bulletin of the national institute of ecology* **15**: 127-31.

Paroha S, Chandra K K and Tiwari K P (2000) Synergistic role of VAM and *Azotobacter* inoculation on growth and biomass production in forestry species. *J Trop For* **16**: 13-21.

Phillips J M and Hayman D S (1970) Improved procedures for clearing and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid 8-60. assessment of infection. *Trans Br Mycol Soc* **55**: 158-60

Piper C S (1966) *Soil Plant Analysis*. Hans Publishers Co., Bombay.

Prasad K and Meghvani M K (2005) Interaction between indigenous *Glomus fasciculatum* and Rhfrobiurn and their stimulatory' effect on growth, nutrient status and nodulation of *Acacia nilotica* (L) Del. Flora and Fauna **11**(1): 51-86

Prasad K G and Rawat V R S (1991) Response of N, P and K by *Acacia nilotica* seedlings. *Indian Forester* **117**(7): 560-67.

Prasad K G, Gupta G N, Mohan S, Nair J M and Deo A D (1984) Fertilization in *Eucalyptus grandis* on severely truncated soil. 11 Biomass Production. *Indian Forester* **110** (2): 142-49.

Prasad P, Prasad P and Nautiyal A R (1998) Response of two multipurpose tree legumes to different fertilizer treatment at nursery level. *Indian J For* **21**(3): 273-79.

Prasad. K (2000) Growth responses in *Acacia nilotica* Del. inoculated with *Rhizobium* and *Glomus fasciculatum* VAM fungi. *J Trop For* **16** (1): 22- 27.

Pratt JH (1982) Role of angiotensin II in potassium-mediated stimulation of aldosterone secretion in the dog. *Journal of Clinical Investigation* **70** (3): 667 - 72

Punj V and Gupta R P (1988) Effect of VA-mycorrhiza and *Rhizobium* on the growth of *Leucaena leucocephala. J Tree Sci* **7**(2): 85-88.

Purohit I, Prasad P and Nautiyal A R (1995) Influence of rhizohial inoculation on nodulation and seedling growth in three nitrogen fixing tree species. *Indian J For* **18**(4): 337-40.

Rachmawati I, Effendi M and Sinaga M (1996) Growth and development performance of multipurpose tree species under the effects of fertilizer. *Bulletin-Penditin-Kehutanan-Kupang* **1**(2): 43-51.

Raghuwanshi R and Upadhyay R S (2006) Vesicular arbuscular mycorrhiza mediated effect on plant growth in a saline-alkali soil in relation to various amendments. *Indian Forester* **132**: 707-24.

Rahangdale R and Gupta N (1999) Vesicular-arbuscualr mycorrhizal association of biomass tree species the tropical forests of Madhya Pradesh. *Indian J For* **22**(1): 62-65.

Raina A K, Pharasi S C and Prasad K G (1990) Application of nutrients on growth of *Acacia catechu* in nursery bed. *Indian Forester* **116** (8): 655-62.

Rajasekar S and Elango R (2011) Effect of microbial consortium on plant growth and improvement of alkaloid content in Withania somnifera (Ashwagandha). *Current Bot* **2** (8): 27-30

Rajendran K and Jayashree G S (2007) Effect of biofertilizers on quality seedling production of *Acacia nilotica*. *J Non-timber For Pro* **14**.1: 1-5.

Rao V M, Niranjan R, Shukla R, Pareek R and Jain H C (2003) Enhancement of growth, nodulation and N2-fixation in *Dalbergia sissoo* Roxb. by *Rhizobium* and *Glomus fasciculatum. J Mycology Plant Pathology* **33** (1): 109-13.

Ravichandran V K and Balasubramanian T N (2006) Sustaining them productivity of *Casuarinas equisetifolia* dual inoculation with *frankia* and VAM. *Indian Forester* **132**: 985-88

Reena J and Bagyaraj D J (1990) Growth stimulation of *Tamarindus indica* by selected VA mycorrhizal fungi. *World J Microb and Biotech* **6**: 59-63.

Reena J and Bagyaraj D J (1990) Response of Ac*acia nilotica* and *Calliundra colothyrus* to different VA mycorrhizal fungi. *Arid Soil Res Rehab* **4**: 216-68.

Reena J and Bagyaraj D J (2009) Response of *Acacia nilotica* and *Calliandra calothyrsus* to different VA mycorrhizal fungi. *Arid Land Research Manage* **44**: 261-68.

Richards I A (1954) Diagnosis and improvement of saline and alkali soils. pp 7-33.

Sadhana B (2014) Arbuscular mycorrhizal fungi (MAF) as a biofertilizer a review. *Int J Curr Microbiology App Sci* **3**(4): 384-00.

Sah S P, Dutta I C and Haque M S (1998) Nursery and field response of sissoo plants (*Dalbergia sissoo*) to *Rhizobium* inoculation. *Silvva-Fennica* **32**(3): 253-59 (Original not seen. Abstr in CAB Abstracts: Entry No. 19980616996).

Sarlach H S, Singh B, and Chauhan S K (2007) Promising agroforestry practices in Punjab. In: Agroforestry system and practices (Ed. Puri S and Panwar P) New India publishing agency, New Delhi. Pp127-47

Sarvanan C G, Jayashella N and Mamatha G (2002) Effect of dual inoculation of *Rhizobium* and *Glomus macrocarpum* on *Albizia lebbek*. *Indian J For* **25** (3): 323-25.

Sengupta A and Chaudhuri S (1995) Effect of dual inoculation of *Rhizobium* and mycorrhiza on growth response of *Sesbania grandiflora* in coastal saline sand dune soil. *Indian J For* **18** (1): 35-37.

Shah S K, Shah R P, Xu H L and Aryal U K (2007) Biofertilizers: an alternative source of nutrients for sustainable production of tree crops. *J Sustain Agriculture* **29** (2): 85-95.

Sharma D and Dutta I C (1994) Response of rhizobial inoculation on germination and growth of seedlings of three leguminous nitrogen —fixing tree species. *Bunko Janakari* **4** (2): 172-75.

Sharma J K, Sankaran K V and Balasundran M (1995) Screening of different mycorrhizal isolates for *Acacia, Casuarina* and *Pterocarpus* grouping in degraded acids soils of Kerala. In: (Adholeya A and Singh S, eds.) *Mycorrhizae: Biofertilizer for the future*, pp 534-40, TERI, New Delhi.

Sharma J K, Sankaran K V, Balasunderan M and Sankar S (1996) Use of mycorrhizal and nitrogen fixing symbionts in reforestation of degraded acid soil of Kerala. In: *Use of Mycorrhiza and Nitrogen Fixing Symbionts in the Revegewtion of Degraded Sites*. An Overview of FORSPA — Supported Research Projects. FURSPA, FAO, Bangkok.

Sharma P R, Niranjan B L and Rao U A (1990) Interaction between *Rhizobium* and mycorrhizal fungi and their stimulator effect on *Acacia nilotica.* In Proceedings of National conference on *Current Trend in Mycorrhizal Research, held at* CSS Haryana Agricultural University, Hisar. India, February 14-16,1990. Record no. 19902302100

Shenoy VV and Kalagudi GM (2005) Enhancing plant phosphorus use efficiency for sustainable cropping. *Biotechnology advances* **23** (7): 501-13.

Singh B (2001) Influence of fertilization and spacing on growth and nutrient uptake in poplar (*Populus deltoides*) nursery. *Indian For* **127**: 111-14.

Singh B P, Ghosal S, Kumar P, Srivastava S C and Choudhary S G (2001) Effect of fertilizer levels on plant growth and biomass production in *Acacia auriculiformis*. *Indian Forester* **24** (1): 38-42.

Singh N and Puri S (2006) Effect of *Rhizohium* and VAM on seedling growth and nutrient uptake in leguminous tree species grown in problematic soils. *Indian J Agrof.* **8**(1): 62-68.

Singh S B and Bhatnagar S (2002) Response of *Acacia nilotica* to nitrogen and phosphorus in water logged sodic soil. *Indian Forester* **128**: 545-50.

Singh S B, Prasad K G, Gupta G N and Maurya G S (1986) Response of two year old *Pinus patula* to N, P and K fertilization. *Indian Forester* **112**(1): 38-42.

Srivastava K K and Srivastava H P (2006) Selection of efficient isolate of VAM for *Tecomella undulata* (SM) SEEM. *Indian J For* **29**(3): 335-37.

Srivastva K K, Mohan V, Verma N (2001) Impact of VAM inoculation on some semi-arid tree species. *Indian Forester* **127** (8): pp 936-40.

Subbarao N S (1984) *Biofertilizer in Agriculture*. Oxford & IBH Publication, New Delhi.Subbiah B V and Asija G L (1956) A rapid procedure for the estimation of available nitrogen in soil. *Curr Sci* **25**: 259-60.

Sumana D and Bagyaraj D J (1998) Selection of efficient VA mycorrhizal fungi for *Dalbergia latifolia* Roxb. *Annals of For* **6** (2): 186-90.

Suvarna C V, Jayasheela N and Mamatha G (2002) Effect of dual inoculation of *Rhizobium* and *Glomus marocarpum* on *Albizia lebbek. Indian J For* **25** (3): 323-25.

Tang M (1994) Effect of inoculation with *Rhizobium* on dry matter yield, nitrogen content and nodulation of *Leucaena leucocephala* cv. CNIA-250 *Pastey-Forrages* **17** (2): 143-47 (Original not seen. Abstr in CAB Abstracts: Entry No. 19950706204).

Tewari G P (1985) Effect of P, K and N on nodulation in cowpea. *Exp Agric* **10**: 253-56.

Toky O P. Beniwal R S and Sharma P K (1994) Interaction between *Rhizobium* inoculation and nitrogen fertilizer application on growth and nodulation of *Acacia nilotica* sub spp. *indica J Arid Env* **27**(1): 49-54.

Totey N G, Verma R K, Verghese M, Shadangi D K, Khatri P K and Pathak H D (2000) Effect of (*Rhizobium*) biofertilizers and varying levels of phosphorus on the growth of forest legumes (*Dalbergia sissoo* and *Albizia procera*). *Indian J For* **23** (2): 205-07.

Totey N G. Khatri P K, Shadangi D K, Badage M and Pathak H D (1997) Effect of *Rhizobium* biofertilizer on growth of seedlings and germination of seeds of *Dalbergia sissoo. Indian J For* **20** (1): 54-56.

Twari P and Saxena A K (2003) Effect of different soil mixtures and fertilizes on the growth of *Dalbergia sissoo* Roxb. seedlings. *Indian J For* **26** (3): 254-59.

Vasishth A, Kaushal R and Kaushal A N (2003) Screening of efficient *Rhizobium* and VAM fungal isolates at varying levels of N and P fertilizers. *Indian J Agrof* **5**(1&2): 80-87.Verma K S, Mishra V K, Chauhan P S and Kansvar B S (1999) Nitrogen and potassium requirements of *Robinia pseudoacacia* Linn. seedlings. *Indian J For* **22** (3): 248-52.

Vassilev N, Medina A, Azcon R and Vassileva M (2006) Microbial solubilization of rock phosphate on media containing agro-industrial wastes and effect of the resulting products on plant growth and P uptake. *Plant Soil* **287** (1-2): 77.

Verma R K, Jamaluddin and Gera M (2002) Effect of arbuscular mycorrhizae on growth and phosphorus uptake in bamboo seedlings. *Indian J Trop Biodiv* **10**: 33-38.

Verma R K, Jamaluddin and Gupta B R (1994) Effect of inoculation of VAM fungi and *Rhizobium* on growth and biomass production in *Acacia nilotica* in nursery. *Indian Forester* **21**: 1089-94.

Verma R K. Khatri P K, Bagde M. Pathak H D and Totey N G (1996) Effect of biofertilizer and phosphorus on growth of *Dalbergia sissoo*. *Indian J For* **19** (3): 244-46.

Walkley A and Black T A (1934) An experimentation of the vegetative method for determining organic and proposed modification of the chronic acid titration method. *Soil Sci* **37**: 38-39.

Yong C C, Juang T C and Chan (1988) Effect of *Rhizobium* inoculation on nodulation and soybean yield in subtropical field. *Fertilizer Soil* **6**: 165-69.

Youssef MMA and Eissa MMF (2014) Biofertilizers and their role in management of plant parasitic nematodes. *J Biotechnol Pharm* **5:**1-6.

Zhang H, Yu Y C, Huang B L, Lu CQ, Wei L X and Wei Y L (2005) Effect of *rhizobia* inoculation on growth of straight stem *Acacia auriculiformis* seedlings and the contents of soil nutritive elements. *J Northeast For Uni* **33** (5): 47-48.

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