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Impact of Eucalyptus (E. tereticornis) Agronomy on Macro Nutritional status of soil of Lucknow district (UP), India

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Abstract

Eucalyptus Is Recognized As A Key Species In Agroforestry Within India, With A Growing Trend Among Farmers Towards Utilizing Clonal Planting Material Of This Species To Maximize Returns In A Reduced Rotation Timeframe. In The Eastern Region Of Uttar Pradesh, The Adoption Of Eucalyptus Is Advancing, Yet The Selection Of Suitable Clones For Plantations Continues To Pose A Significant Challenge. Agroforestry Provides Various Benefits To Farmers, Establishing Itself As A Sustainable Alternative To Monoculture Systems. The Present Study Investigated The Influence Of Eucalyptus Plantations On Various Physical And Chemical Characteristics Of Soil In The Lucknow District Of Uttar Pradesh, India. Eucalyptus Was Initially Embraced Upon Its Introduction To India; However, It Was Later Discovered That Its Rapid Growth Led To A Significant Reduction In Soil Nutrients, Resulting In Diminished Soil Fertility In Farming Areas. This Situation Necessitated An Evaluation Of The Effects Of Eucalyptus On Soil Nutrient Levels In The Lucknow District. The Research Revealed That Soil Ph And Nutrient Quality Experienced Considerable Changes Following The Introduction Of Eucalyptus.

The Analysis Encompassed Soil Ph, As Well As The Concentrations Of Calcium, Magnesium, Organic Carbon, And Total Nitrogen. Although The Study Indicates A Complementary Relationship, A Significant Limitation Was The Farmers' Insufficient Awareness Of Eucalyptus's Allelopathic Properties.

Key Words:- Eucalyptus, Agroforestry System, Soil Properties, Organic Carbon, Total Nitrogen, Soil Fertility

Introduction

With an estimated global acreage of 10 to 15 million, eucalyptus is the second most common hardwood species planted worldwide, behind pines [1]. The remarkable capacity of eucalyptus to adapt to a broad range of settings and compatibility for diverse climatic circumstances has made it one of the most popular fast-growing tree species [2].

The most often used plant to be planted along the boundaries or in bunds of agricultural land is eucalyptus, which is also well-accepted and integrated into India's agroforestry [3]. By changing or adjusting land use methods, farmers have embraced a variety of agroforestry tactics to improve both their economic situation and the productivity of the land [4]. Any alteration to change in their land use pattern from agriculture to agroforestry or plantations may cause change in soil nutrient status of the fields [5].

Eucalyptus plantings have the potential to restore degraded lands by means of stabilizing soils, augmenting the generation of above-ground litter, improving soil nitrogen status, and increasing soil organic matter [6]. Due to allelopathy and competition with other species for water, growing eucalyptus in low-rainfall areas may have a negative influence on the ecosystem. Other plants that grow close to eucalyptus trees may be affected by the allelopathic effects of eucalyptus.

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This is blaming for decreased crop yields brought on by nutrient depletion and the generation of harmful exudates (allelochemicals) [7]. A high carbon to nitrogen ratio litter fall was provided by eucalyptus species. Its breakdown hence takes a long period and does not recycle macronutrients like nitrogen (N) and phosphorus (P). This is because the plant litter fall has greater concentrations of lignin and allelopathic compounds, which impede its breakdown [8].

Plantations of Eucalyptus species have a disastrous effect on the physico-chemical characteristics of the soil, reducing the amount of organic matter in the soil and adversely affecting soil hydrology [9]. The increased concentrations of iron (Fe) and manganese (Mn) in the soil beneath short-rotation eucalyptus are a direct result of eucalyptus cultivation. The leaves of eucalyptus trees contribute to soil degradation and are resistant to decomposition [10]. When eucalyptus is grown as a short-rotation crop for high biomass yield, it leads to a swift depletion of soil nutrients. Furthermore, the oil present in eucalyptus leaves serves as a biocide, preventing the proliferation of most soil bacteria that facilitate the breakdown of the leaves.

The highest value was found in eucalyptus plantation land uses compared to agricultural land uses in almost all parameters, particularly in soil organic carbon and soil organic matter. This results from the recycling of nutrients caused by the breakdown of various tree sections [11]. One of the most popular agroforestry species in India is eucalyptus, and farmers there are increasingly turning to clonal planting material of this species in order to increase yields over a shorter rotation time. Although eucalypts are getting closer to being adopted on a bigger scale in the eastern region of the Indian state of Uttar Pradesh, finding appropriate clones for plantations remains a significant difficulty.

Farmers gain from agroforestry, which makes it a viable substitute for monoculture [12]. Because eucalyptus is allelopathic, this study is conducted with the idea that it negatively affects both the soil and intercrops. Consequently, the objective of the present study is to explore the feasibility of utilizing Eucalyptus clones in intercropping practices to boost farmers' income while improving the long-term productivity, sustainability, and profitability of agricultural systems in northern India. [13]. The present study aimed to evaluate the nutrient quality of the soil beneath eucalyptus plantations, whether in the context of bund plantings or across the entire field.

Material & methods

Study area- The district of Lucknow formed the central part of the province of Avadh. The district lies between the parallels $26^0$30’ and $27^0$10’ north latitude and $80^0$30’ & $81^0$13’ east longitude. The soil samples were collected from Malihabad block of Lucknow district. Various sampling sites indicated in fig. 1. The Eucalyptus growing villages of Bhatoiya, Pahaadapur, Sahilamau, Saraavaan, Hariharapur, Jauriya, Sahijana, Tikaitaganj, Phatehapur, Mandauli, Khalispur, Tilsua, Surgaula, Phirojapur, Navi Nagar, Saradapur, Purava, Ataura, Biraahimapur & Allupur, respectively comes under the block Malihabad and selected as study area.

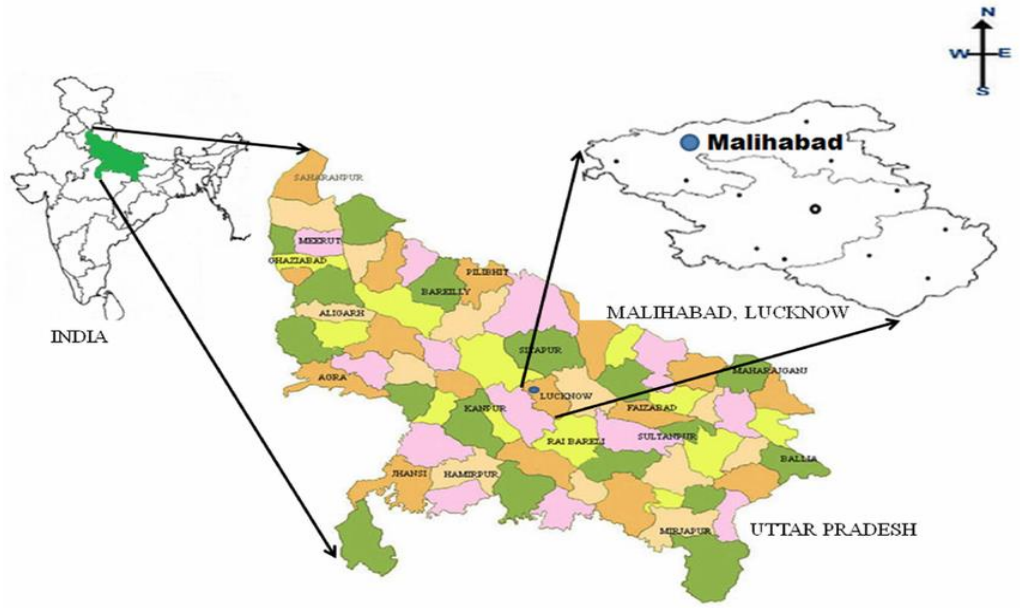

Fig. 1 – Various sampling sites of Lucknow District

Soil sampling was done **twice in bund plantations** of eucalyptus of **1-year and 3-year-old plantations**; before monsoon in the month of **June, 2024** and after monsoon in the month of **August, 2024** at 0-5 m, 5-10m and 10-15m. To conduct an analysis of pH and soil nutrients, soil samples were collected from a depth of 0 to 15 cm. The air-dried soil samples were subsequently placed in a glass jar for further examination after being processed through a 2 mm sieve. Standardized protocols were employed for the analysis; specifically, a pH meter was utilized to measure the soil's pH. The flame photometric method was applied to assess potassium levels, while total nitrogen was determined using the Kjeldahl method [14]. Organic carbon content was evaluated through the Walkley and Black method, phosphorus was analyzed using the Olsen method [15], and calcium and magnesium concentrations were measured via the EDTA titration method.

Result & Discussion

Soil pH:

In agroecosystems where there was no eucalyptus plantation (NEP) pH value decline from alkaline (8.2) towards more neutral (7.6). In 1- year- old eucalyptus plantations on bund (BEP1) the pH values fluctuate between 7.2 to 8.5. The 3-year-old eucalyptus plantations (BEP3) on the bund show a reverse trend in pH values when compared to the NEP. The pH values show variation between 7.5 to 8.5. The 3-year-old full field eucalyptus plantations (FEP3) did not show any significant differences in the pH values between 0-15m distances, its variation noticed between 7.8 to 8.1. Similar trends followed during the month of August also.

The pH of the soil is significantly impacted by eucalyptus plantations. The pH of the soil is influenced by a number of variables, including soil microbial activity, CEC, and BD. Most researches have reported that soil pH has decreased after plantations, however the current study also finds that soil pH tends to decline when land use changes from agriculture to eucalyptus plantations. Many employees also observed a decrease in soil pH following the installation of eucalyptus [16]. When compared to soils in unspoiled forests, the pH of the soil in eucalyptus plantations was much lower. Eucalyptus species immobilizing soil exchangeable bases may be the origin of the reasons, leading to an increase in ions such Al^{3+} and H^+ in the soil [17].

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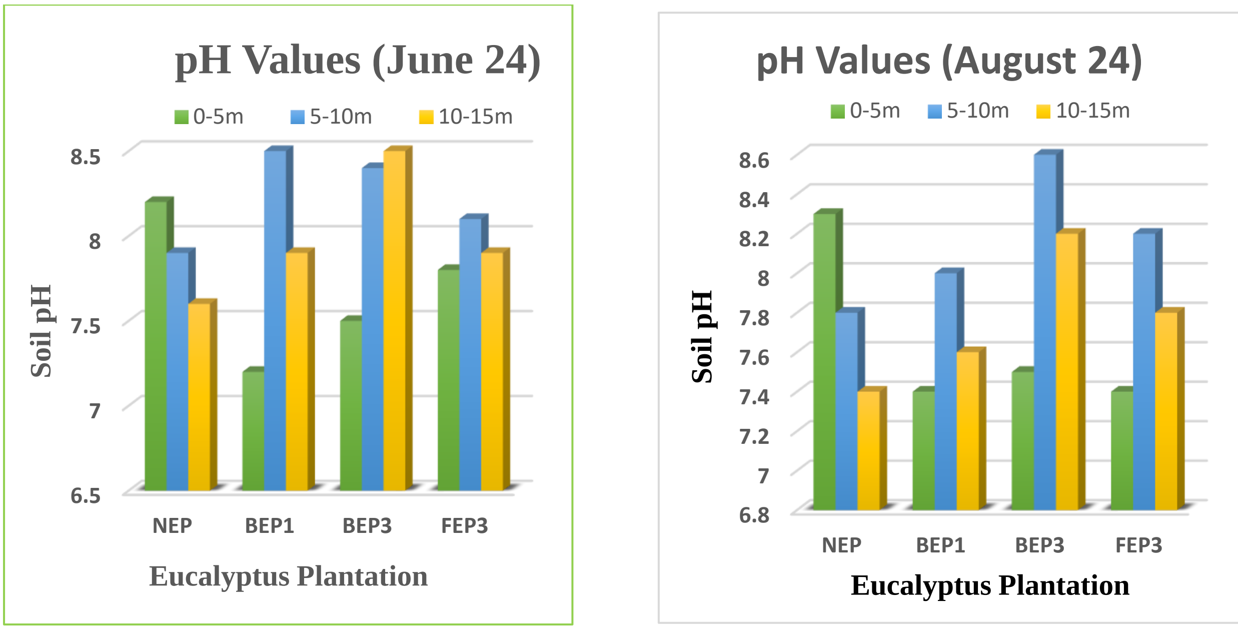

Fig.2. Soil pH at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus.

Organic Carbon:

Organic carbon percentage values were significantly higher at 0-5m in the BEP1 sites, however the concentration of organic carbon in BEP3 showed higher values at 5 to10 m, but in FEP3 the corresponding values showed higher concentration only at 10 to 15 m during the month of June. However, this trend reversed in the month of September where the percentage of organic carbon increased up to 5 m distance for BEP3, and for BEP3 and FEP 3 they did not show any significant difference in organic carbon percentage at 5 to 10 m and 10 to 15 m distance.

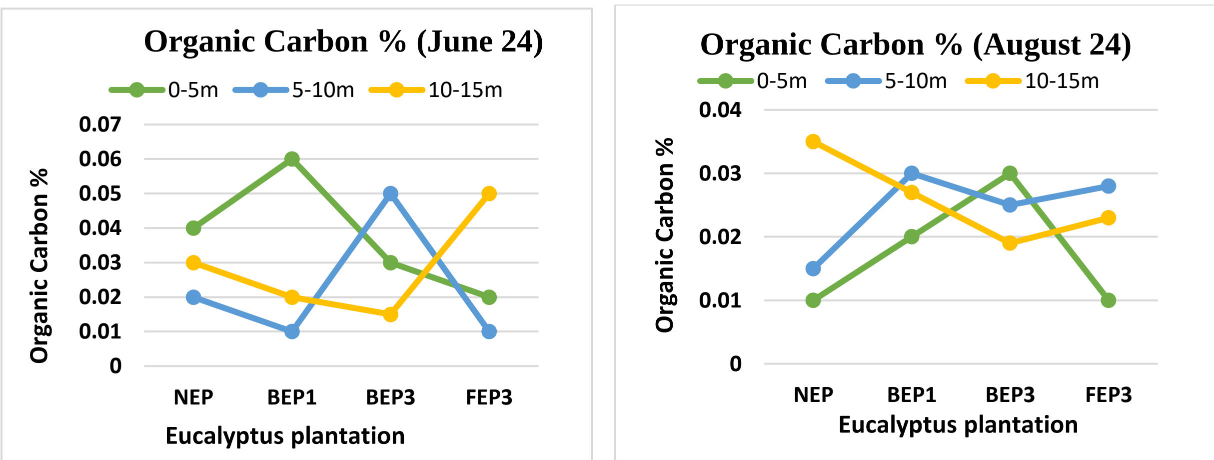

Fig.3. Soil Organic Carbon (%) at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus.

Total Nitrogen:

Total nitrogen percentage was significantly higher at 0 to 5 m in all the plantation fields. The total nitrogen concentration was also significantly higher at 10 to 15 m, but the nitrogen concentration declined significantly with the increase in the distance from 10 to 15m in FEP3. In all the sites except FEP3 the nitrogen concentration declined significantly with the increase in the distance up to 15 during the month of June. In August also the trend was similar with the total nitrogen concentration being significantly higher up till 5m distance at all the sites and subsequent decline in concentration of Nitrogen with increase in the distance up to 15 m. However, at 5m the nitrogen availability was significantly higher in BEP3 as compared to other sites.

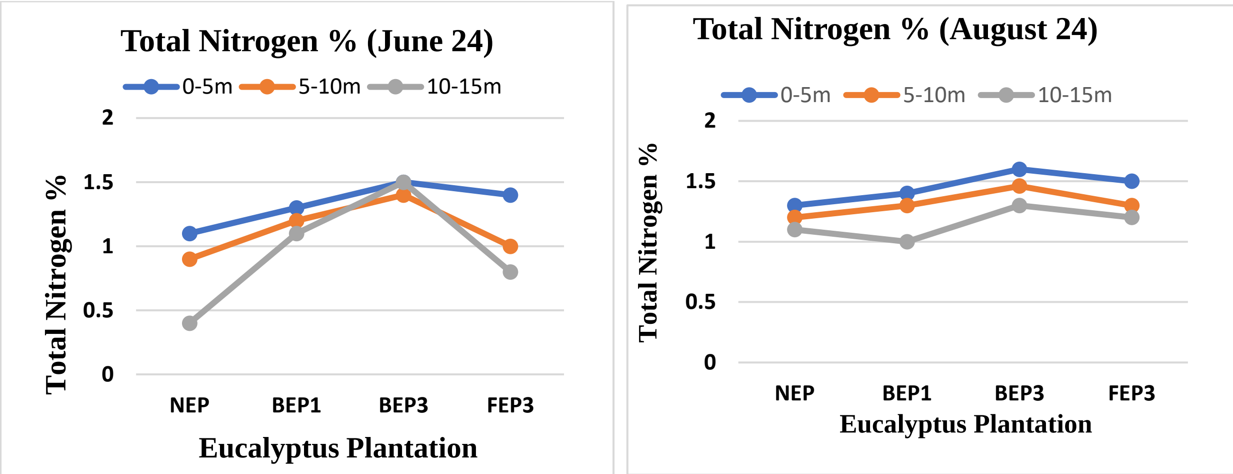

Fig.4. Soil Nitrogen (%) at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus.

Significant quantities of nutrients are exported during the harvesting of Eucalyptus spp. plantations, which causes a drop in soil nutrients such total N and accessible P [18]. Due in part to their rapid growth and incapacity to fix nitrogen, eucalyptus species have high rates of soil nutrient uptake; as a result, the establishment of eucalyptus plantations has been demonstrated to have negative short- and long-term effects on soil fertility and quality [19].

After eucalyptus plants, the total nitrogen content rose in our investigation. This might be due to fertilizer-induced increases in the concentrations of N, P, and S in leaf litter; however, since eucalyptus leaf decomposition is slow, soil N concentrations tend to rise over time [20].

Phosphorous:

Phosphorous percentage was significantly higher at 0 to 5 m in all the plantation fields. The Phosphorous concentration was also significantly higher at 10 to 15 m, but declined significantly with the increase in the distance from 10 to 15m in FEP3. In all the sites except FEP3 the phosphorus concentration declined significantly with the increase in the distance up to 15 during the month of June. In August also the trend was similar with the phosphorous concentration being significantly higher up till 5m distance at all the sites and subsequent decline in concentration of phosphorous with increase in the distance up to 15 m. However, at 5m the 'P' availability was significantly higher in BEP1 as compared to other sites. A high carbon to nitrogen ratio litter fall was provided by eucalyptus species. Its breakdown hence takes a long period and does not recycle macronutrients like nitrogen (N) and phosphorus (P). This is because the plant litter fall has greater concentrations of lignin and allelopathic compounds, which impede its breakdown. Allelochemicals can remain in the soil for several years, impacting nearby plant species and crops [21].

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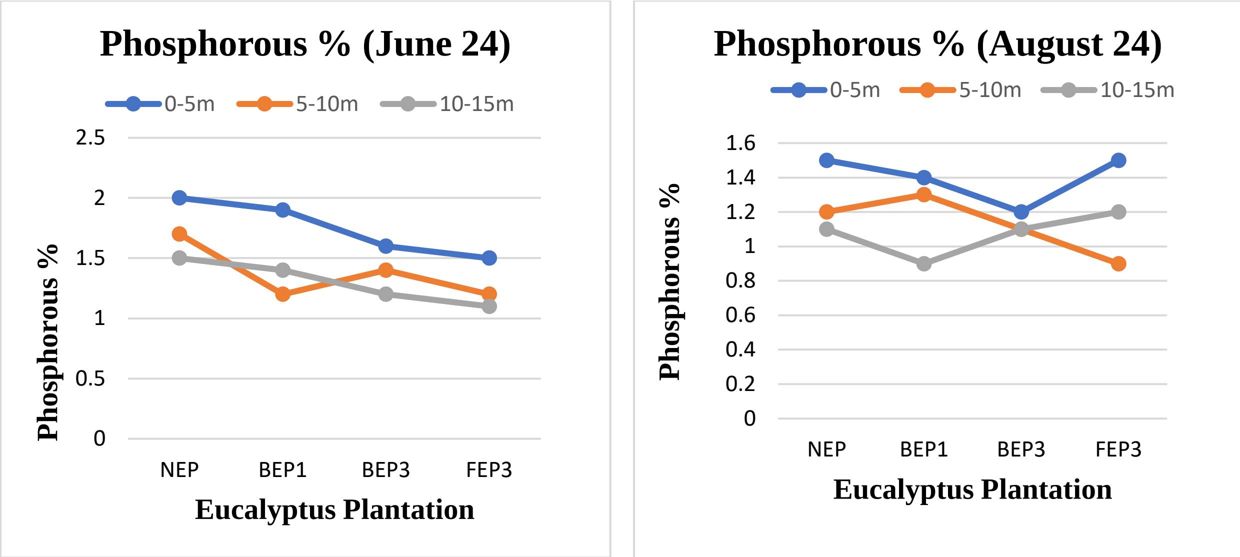


Fig.5. Soil Phosphorous (%) at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus.

Potassium:

Potassium percentage was significantly higher at 0 to 5 m in all the plantation fields but declined significantly with the increase in the distance from 10 to 15m in FEP3. In all the sites except BEP3 the potassium concentration declined significantly with the increase in the distance up to 15 during the month of June. In August also the trend was quite different with the potassium concentration being significantly higher up till 5m distance at all the sites and subsequent decline with increase in the distance up to 15 m. However, at 5m the 'K' availability was significantly higher in NEP as compared to other sites. An important nutrient for forest ecosystems is potassium. In very worn soils, such as those found in tropical eucalyptus plantations, it may be severely restricting tree development. Potassium (K) plays a crucial role in the interception of light by the canopy, the process of carbon fixation, and the transfer of carbon from leaves to various sinks, thereby influencing both the water and carbon cycles [22]. The application of K fertilizer positively impacted tree growth rates, which remained significant until the end of the six-year rotation, with the growth rates of K-fertilized trees occasionally reaching up to three times those of trees lacking sufficient potassium [23].

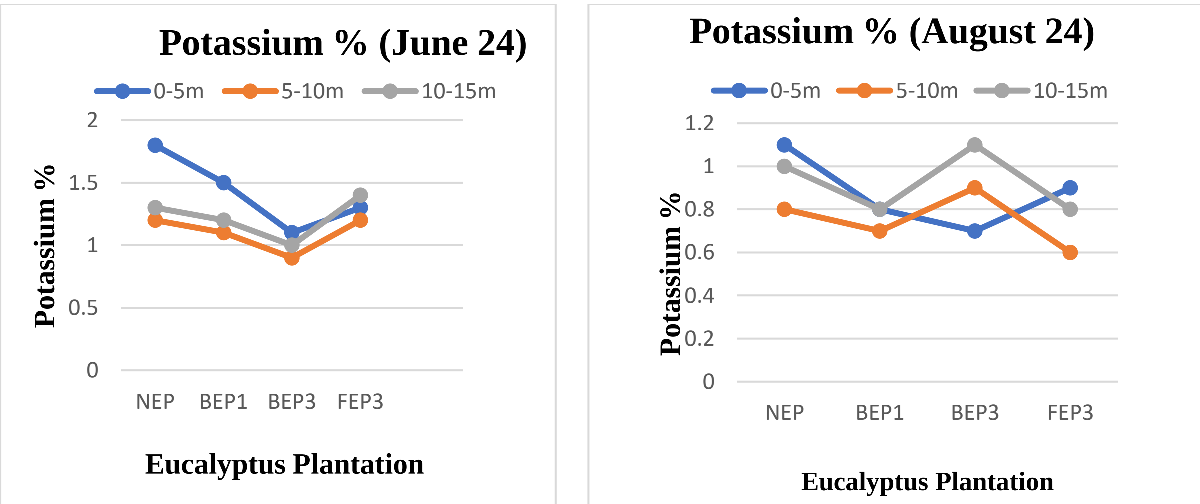
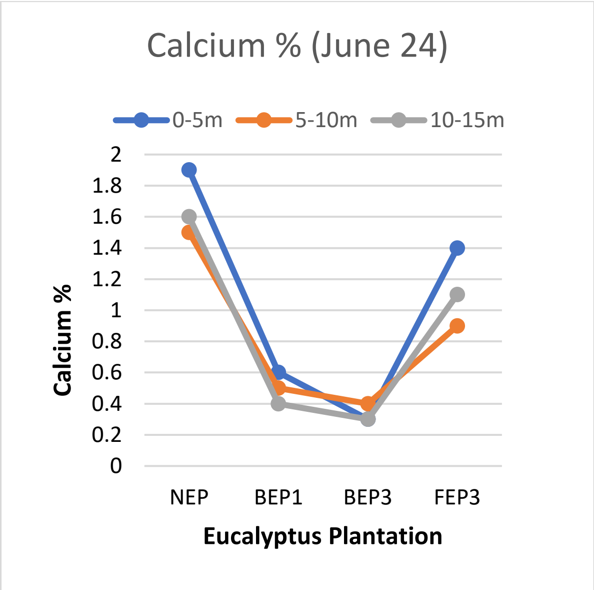


Fig.6. Soil Potassium (%) at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus.

Soil Calcium & Magnesium:

Soil calcium percentage was significantly higher between 0 to 5m distance in NEP during both the month of June and August compared to other three sites of eucalyptus plantations. Calcium concentration was lowest in BEP3 at all the three distances measured during the months of June to August. This trend was constant at all the sites. Ca has been highly demanding in Eucalyptus plantations for its growth and productivity. The immobilization of exchangeable bases such as Ca^{2+}, Mg^{2+}, and K^{+} over time leads to a depletion of these bases in the soil, resulting in a decrease in pH levels within plantation soil. Consequently, this reduction in pH correlates with a diminished level of soil base saturation. In Eucalyptus plantations, the application of calcium and magnesium fertilizers through lime, gypsum, or ash treatments has been shown to enhance stem wood volume by as much as 60% [24].



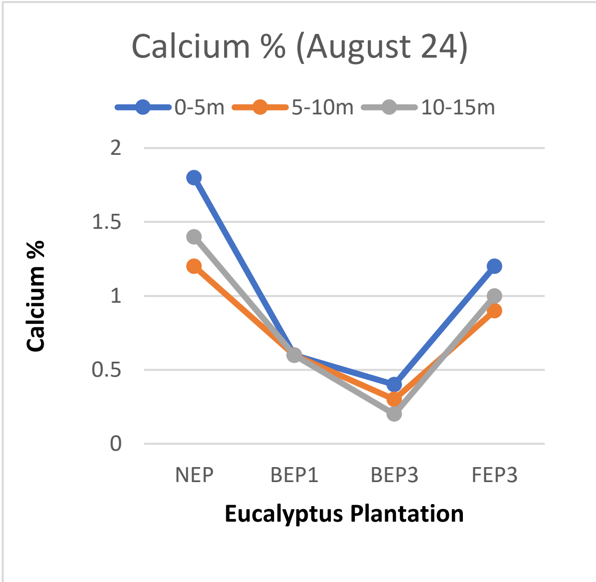
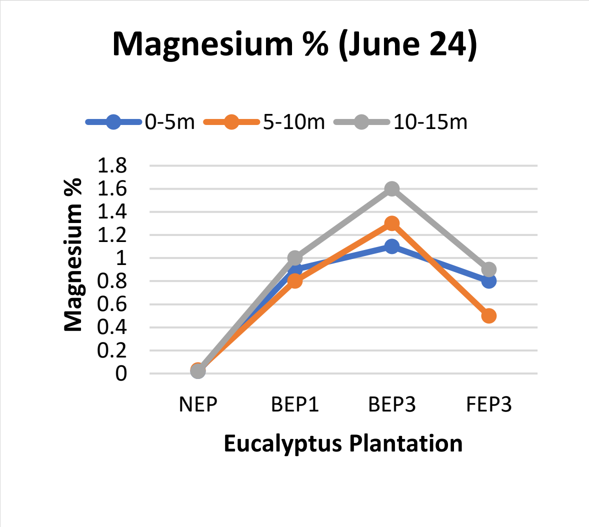
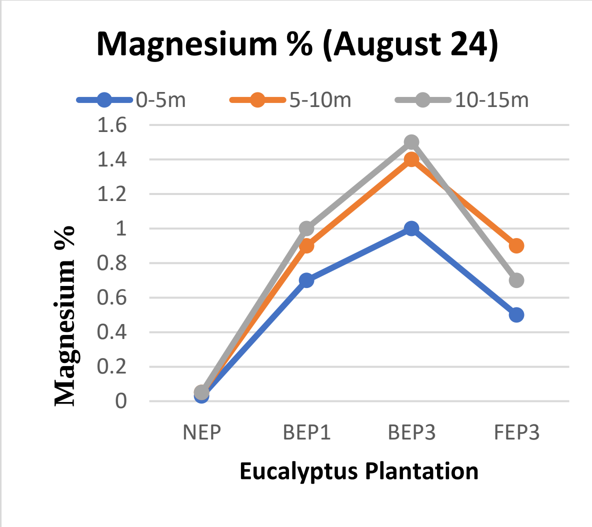


Fig.7. Soil Calcium (%) at different distance (0-5m,5-10m,10-15m) of Bund and Full field plantations of Eucalyptus

In every site, the concentration of magnesium exhibited the opposite trend as that of calcium. In BEP3, the concentration rose noticeably as the distance from 0 to 15 m increased. The land devoid of eucalyptus plantations (NEP) had the lowest concentration. August saw a similar pattern in every location. Large amounts of calcium and magnesium can build up in eucalyptus plantations, particularly on very productive locations. Mg accumulation is greater in the first two years and thereafter stabilizes, whereas Ca accumulation is proportionate to biomass accumulation throughout the age [25].





Conclusion

The findings showed that applying lime to eucalyptus planting sites can increase soil fertility by boosting minerals including calcium, magnesium, nitrogen, phosphorus, potassium, and organic carbon while also maintaining soil pH. Certain types of eucalyptus trees are capable of drawing significant amounts of moisture and nutrients from the soil. They also possess the capacity to produce more biomass than any other type of tree. However, if the tree's rotation age is not appropriately controlled, the pace at which biomass is created is slowed down, and a significant quantity of soil moisture and nutrients are lost. Also, because Eucalyptus tree species have a significant ability to collect moisture and nutrients from the soil, the location of the tree's planting must be distant from a crop field. Since eucalyptus plantations have decomposing litter, they have better effects on the physical and chemical properties of soil than heavily farmed agricultural land. Farmers, businesses, and legislators looking to choose a eucalyptus-based agroforestry model wisely will find this study to be beneficial overall.

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References

[1] F. J. Hutapea, C. J. Weston, D. Mendham, and L. Volkova, "Sustainable management of Eucalyptus pellita plantations: A review," *For Ecol Manage*, vol. 537, p. 120941, Jun. 2023, doi: 10.1016/J.FORECO.2023.120941.

[2] "Influence of Eucalyptus Agroforestry on Crop Yields, Soil Properties, and System Economics in Southern Regions of India - Google Search." Accessed: Oct. 13, 2024.

[3] C. N. Vigo, F. E. Oclocho-Garcia, D. Iliquín Trigoso, and M. Oliva-Cruz, "Influence of Eucalyptus globulus plantations on soil characteristics at different altitudinal levels," *Trees, Forests and People*, vol. 18, Dec. 2024, doi: 10.1016/j.tfp.2024.100677.

[4] "(PDF) Effect of Different Aged Eucalyptus Plantations on Soil Nutrient of Agricultural Fields of Rae Bareli District of Uttar Pradesh, India." Accessed: Oct. 20, 2024

[5] D. M. Sandoval López, M. F. Arturi, J. F. Goya, C. A. Pérez, and J. L. Frangi, "Eucalyptus grandis plantations: effects of management on soil carbon, nutrient contents and yields," *J For Res (Harbin)*, vol. 31, no. 2, pp. 601–611, Apr. 2020, doi: 10.1007/S11676-018-0850-Z.

[6] A. E. Lugo and R. B. Waide, "Catastrophic and background disturbance of tropical ecosystems at the Luquillo Experimental Forest," *J Biosci*, vol. 18, no. 4, pp. 475–481, Dec. 1993, doi: 10.1007/BF02703080.

[7] Bekele Tona Amenu (2020), Review on Impact of Eucalyptus Plantation on the Soil, International Journal of Scientific Research in Civil Engineering, Volume 2, Issue 2, pp-37-43. - Google Search." Accessed: Oct. 20, 2024

[8] Aweto, A.O., & Moleele, N. M. (2005). Impact of Eucalyptus camaldulensis plantation on an alluvial soil in south eastern Botswana. International journal of environmental studies, 62(2), 163-170 - Google Search." Accessed: Oct. 20, 2024.

[9] Tererai, F., Gaertner, M., Jacobs, S. M., & Richardson, D. M. (2014). Eucalyptus camaldulensis invasion in riparian zones reveals few significant effects on soil physico-chemical properties. River Research and Applications, 7(4), 1–12. - Google Search." Accessed: Oct. 20, 2024.

[10] "Changes of Selected Soil Properties in a Floodwater-Irrigated Eucalyptus Plantation in the Gareh Bygone Plain, Iran: Arid Land Research and Management: Vol 25, No 1." Accessed: Oct. 20, 2024.

[11] SANGAM BADESHRA1, K K BHARDWAJ1*, SONIA DEVI2, GARIMA DAHIYA1 and R S DHILLON1(2021), Evaluation of soil micronutrients under different spacing of Eucalyptus-based agroforestry system, Indian Journal of Agricultural Sciences 91 (11): 1557–60. - Google Search." Accessed: Oct. 20, 2024.

[12] Cook RL, Binkley D, Stape JL (2016): Eucalyptus plantation effects on soil carbon after 20 years and three rotations in Brazil. For Ecol Manag 359: pp 92–98 - Google Search." Accessed: Oct. 20, 2024.

[13] J. H. T. Rocha, B. du Toit, and J. L. de M. Gonçalves, "Ca and Mg nutrition and its application in Eucalyptus and Pinus plantations," *For Ecol Manage*, vol. 442, pp. 63–78, Jun. 2019, doi: 10.1016/J.FORECO.2019.03.062.

[14] Allen S.E.H.M. Grimshaw and A.P. Rawland (1986), Methods in Plant Ecology (Eols P.D. Moore and S.B. Champmen) pp 285 – 344. - Google Search." Accessed: Oct. 20, 2024.

[15] Olsen, S.R. & Sommer, L.E. (1982), Phosphorus in methods of soil analysis part 2 (Eds. A.L. Page et al.) Agron 9 Am Soc Agron, Madison, Wiscosin, 403 – 430. - Google Search." Accessed: Aug. 30, 2024.

[16] C. Rhoades and D. Binkley, "Factors influencing decline in soil pH in Hawaiian Eucalyptus and Albizia plantations," *For Ecol Manage*, vol. 80, no. 1–3, pp. 47–56, 1996, doi: 10.1016/0378-1127(95)03646-6.

[17] C. N. Vigo, F. E. Oclocho-Garcia, D. Iliquín Trigoso, and M. Oliva-Cruz, "Influence of Eucalyptus globulus plantations on soil characteristics at different altitudinal levels," *Trees, Forests and People*, vol. 18, Dec. 2024, doi: 10.1016/j.tfp.2024.100677.

[18] J. R. de Morais, R. M. V. Castilhos, C. L. Lacerda, L. F. S. Pinto, and F. S. Carlos, "Carbon and nitrogen stocks and microbiological attributes of soil under eucalyptus cultivation in the Pampa biome of southern Brazil," *Geoderma Regional*, vol. 25, p. e00392, Jun. 2021, doi: 10.1016/J.GEODRS.2021.E00392.

[19] Lemenih M, Kassa H (2014) Re-Greening Ethiopia: History, Challenges and Lessons. Forests 4: 1896-1909. - Google Search." Accessed: Oct. 20, 2024.

[20] C. Ribeiro, M. Madeira, and M. C. Araújo, "Decomposition and nutrient release from leaf litter of Eucalyptus globulus grown under different water and nutrient regimes," *For Ecol Manage*, vol. 171, no. 1–2, pp. 31–41, Nov. 2002, doi: 10.1016/S0378-1127(02)00459-0.

[21] B. Mengistu, F. Amayu, W. Bekele, and Z. Dibaba, "Effects of Eucalyptus species plantations and crop land on selected soil properties," *Geology, Ecology, and Landscapes*, vol. 6, no. 4, pp. 277–285, 2022, doi: 10.1080/24749508.2020.1833627.

[22] I. Cornut *et al.*, "Potassium limitation of wood productivity: A review of elementary processes and ways forward to modelling illustrated by Eucalyptus plantations," *For Ecol Manage*, vol. 494, Aug. 2021, doi: 10.1016/j.foreco.2021.119275.

[23] R. Chambi-Legoas, M. Tomazello-Filho, J. P. Laclau, and G. Chaix, "Potassium fertilization enhances xylem plasticity and growth recovery of Eucalyptus grandis trees in response to drastic changes in water availability," *For Ecol Manage*, vol. 528, p. 120656, Jan. 2023, doi: 10.1016/J.FORECO.2022.120656.

[24] A. Demessie, B. R. Singh, R. Lal, and L. T. Strand, "Leaf litter fall and litter decomposition under Eucalyptus and coniferous plantations in Gambo District, southern Ethiopia," *Acta Agric Scand B Soil Plant Sci*, vol. 62, no. 5, pp. 467–476, Jul. 2012, doi: 10.1080/09064710.2011.645497.

[25] R. Chambi-Legoas, M. Tomazello-Filho, J. P. Laclau, and G. Chaix, "Potassium fertilization enhances xylem plasticity and growth recovery of Eucalyptus grandis trees in response to drastic changes in water availability," *For Ecol Manage*, vol. 528, Jan. 2023, doi: 10.1016/j.foreco.2022.120656.