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# Litterfall guided soil nutrient return in Eucalyptus based agroforestry system

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Here, the arrangement of litterfall and nutrient return to the soil by the seven-year-old plantations of Eucalyptus under different spacings established on sodic wastelands in northern India was determined. The litterfall was sorted into leaf wood and miscellaneous. Further, the seasonal variation of litterfall obtained under three different spacings was recorded. Maximum leaf litter production was observed in 3×3 m spacing followed by 6×1.5 m during the winter season. Whereas, the minimum leaf litter was recorded in 17×1×1 m spacing. Similarly, the maximum wood litter production was observed at the spacing of 3×3 m spacing in rainy season followed by 6×1.5 m.The weights of nutrients returned through annual litterfall in 3×3 spacing returned the highest amount of N (2.16 g/$m^2$ year) followed by 6×1.5 and 17×1×1 spacing.. Whereas, two-year data of litterfall of *E. tereticornis* showed the 17×1×1 spacing returned the highest amount of P in next year through leaf litter followed by 6×1.5 and minimum 3×3 spacing. Overall, this study provides important information regarding the litterfall guided soil nutrient return to the soil under North Indian conditions.

**Keywords:** Agroforestry, Eucalyptus, Litterfall, Sodic soils, Wasteland
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*Eucalyptus tereticornis* is an important member of the family Myrtaceae. It is well adapted to a wide variety of edaphic and climatic conditions[1]. Moreover, this thrives well under the wide range of soil conditions but needs deep, fertile, well-drained loamy soil with sufficient moisture for best growth. It does not fit into the extremely hilly area, dry and eroded rained waterlogged area. Eucalyptus is used for several works likewise firewood, pulp and paper, constructional timber, electric pole, railway sleepers, plywood and particle board production[2]. Additionally, oil and tannin are also extracted from some Eucalyptus species. *E. tereticornis* was exported from Australia and introduced in India in 1919. It is a vigorous growing and hardy tree with excellent coppicing power. It has established as a hardy and extensive plantation throughout the country. Clonal technology was used as a tool to increase productivity, especially for *E. tereticornis*[3]. *E. tereticornis* proved reasonably useful in its edaphological adaptation, out of 170 species tested in India. Its production was undertaken to popularise to improve the earnings of farmers[4].

In the present situation, the demand for wood and wood-based products is increasing significantly; emphasis is on growing short rotation species to link the gap between the growing demand and too little supply of wood[5]. Eucalyptus provides the raw material for the pulp and paper industries, so it is crucial that planting stock of high genetic quality be used to boost the yield from the plantation. Reduced availability of pulpwood in India bent the need for quick-growing species. The biggest single urge to plant Eucalypts in large scale plantations was provided by the demand for wood fibre for the paper industry[6,7]. These problems have limited the large scale, commercial breeding of Eucalyptus and other forest tree species to random mating of selected trees on very limited experimental extentonly as in seed orchards. Information regarding realised gains from Eucalyptus improvement programmers is very scanty[8].

The production of litter plays a fundamental role in the biogeochemical cycle of organic matter and mineral nutrients, thus emerging as a critical component in the functioning and stability of forest ecosystems. Organic residues coming in the form of litterfall and accumulated on the ground are a

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significant reservoir of organic matter and nutrients and influence or regulate most of the functional processes occurring throughout the ecosystem[9,10]. In forest ecosystems, litter production depends primarily on the productivity of plant communities, which in turn is affected by the climatic and edaphic conditions under which forests develop, their biological characteristics, species composition, and the density, age and level of maturity of the stand. Litter is usually the dried part of plants fallen on the ground. The litter mostly contains leaves, flowers, fruits, seeds and twigs. In the forest ecosystem, tree leaves are periodically or continuously dropped on the ground[11]. This leaf litter decomposes and releases a substantial amount of nutrients into the soil and directs the regulatory mechanism of nutrient cycling and organic matter[12]. Thus, litterfall exerts a significant influence on physical, chemical and biological characteristics of soil as well as further growth of trees[13]. Here we have studied the effects of nutrient return by the Eucalyptus based agroforestry system under the sodic soils of Northern India.

## Materials and Methods

The experimental site is situated at 29º 09' N latitude and 75º 43' E longitudes situated in the semi-arid region of north-west India. The mean monthly values of weather parameters viz., temperature, relative humidity and rainfall recorded at the meteorological observatory located at Research Farm, CCS Haryana Agricultural University, Hisar. Soil samples nearly 30 cm deep were being gathered for examining soil profile. The pH was calculated using a pH meter with a glass electrode and Ec by conductivity meter. Soil natural and organic C was analyzed by immediate titration process[14] and N, by the micro-Kjeldahl method[15]. The sum of $NH_4$-N and $NO_3$- N was reflected as available N. Available P was determined inside of a dilute acid-fluoride extracted soil having chlorostannous-reduced phosphomolybdic blue colour process. Available potassium (K) was analyzed with flame photometer after leaching soil with one N ammonium acetate alternative[15].

The soil is impoverished in natural and organic C and nutrient status. A hardpan of 20-30 cm thickness is commonly found within the 1 m depth of the soil. Presence of $CaCO_3$ concretions is the dominant characteristic of older alluvium. For the measurement of litterfall six litter traps were being randomly placed on the floor of each spacing. Each trap was 100×100 cm and had 12-cm high wooden sides. Litter was gathered for one year at monthly intervals from June till May. The litter from each trap was collected independently and fractionated into various litter components, viz., leaf, woody and miscellaneous. The samples were oven-dried at 80ºC to achieve constant weight. Monthly samples for each litter component from the different spacings of each spacing were being pooled together to form annual samples.

The composite samples were being ground separately and analysed for various nutrients. Nitrogen was determined by micro- Kjeldahl procedure[16]. Phosphorus was evaluated by the phosphomolybdic blue colour colourimetric process as described elsewhere[15]. Whereas, K, Ca, Mg, Cu, Zn, Mn and Fe were extracted by wet digestion of 0.5 g plant material inside of a strong acid mixture consisting of 10 mL concentrated $HNO_3$ + 3 mL concentrated $H_2SO_4$ + 1 mL $HClO_4$ by the same process as followed in the soil analysis[15]. K was determined by flame photometer while Ca, Mg, Cu, Zn, Mn and Fe were determined by atomic absorption spectrophotometer. Data for various litter components gathered in different months from all the tree spacings were subjected to analysis of variance[17]. Additionally, seasonal means were calculated from monthly collections to detect seasonal differences in litterfall. Finally, annual totals were being calculated as the sum of all groups. The standard error (± one SE) was also calculated for the concentration of each nutrient in all litter components of the different spacings[17]. Nutrient concentration was multiplied by the weight of annual litterfall to calculate the amounts of nutrients reverted to the soil.

## Results and Discussion

Wooden traps (1.0 m×1.0 m), having perforated bottom were randomly placed at 150 cm above the ground in all the treatments (6 boxes in each) and litter was collected every month, starting for Dec. 2014 up to December 2016. The minimum leaf litter production was recorded in 17×1×1 (33.85g/$m^2$) and woody litter production at 3×3 spacing (14.54 g/$m^2$) in rainy season followed by 6×1.5 (14.52 g/$m^2$) while maximum miscellaneous litter production was in summer season at 3×3 spacing (0.92 g/$m^2$) followed by 6×1.5 (0.76 g/$m^2$) and minimum miscellanies litter production in summer season at 17×1×1 (0.39 g/ $m^2$)

(Table 1). In the next year, the seasonal pattern of aboveground litterfall in the plantation is shown in Table 2. Maximum woody litter production at 6×1.5 spacing (15.77 g/$m^2$) in rainy season followed by 3×3 (14.99 g/$m^2$) while last one observed maximum miscellanies production in summer season at 3×3 spacing (1.00 g/m2) followed by 6×1.5 (0.90 g/$m^2$) and minimum miscellanies litter production in summer season at 17×1×1 (0.43 g/$m^2$ ) (Table 2).

**Nutrient concentration under the different spacing nutrient status of eucalyptus plants**

In *Eucalyptus* plants growing at different spacing are presented under subheads in Table 3. Among leaves, the maximum nitrogen (0.92%) was recorded under 17×1×1 m spacing followed by 6×1.5 m. Among branches maximum concentration of nitrogen 0.42% was recorded in 17×1×1 m spacing followed by 6 × 1.5 m (0.41%) and minimum in 3×3 m spacing (0.41%). Like N. P concentration at spacing, i.e., 17x1×3 m was significantly more than the other two spacing's while in 6 x 1.5 m, it was significantly more 3×3 m spacing and. Minimum P concentration in leaves of *Eucalyptus* was recorded at 3x3 m spacing which was significantly less than the other two spacing's. Among leaves, highest concentration of 0.15% was recorded in leaves at 17×1×1 spacing, followed by, i.e., 0.14%, 6 x 1.5 m spacing (0.13%) and minimum in 3×3 m spacing. In case of wood the P concentration varied from 0.16% (in 17×1×1 m) to 0.11% (in 6 x 1.5 m). The same trend was recorded in the concentration of miscellaneous, i.e., high P (0.116%) was recorded in 17×1×1 followed by 0.112 % 6×1.5 m and minimum in 0.108% in 3×3 m spacing. The concentration of Potassium in different plant parts of Eucalyptus grown in different spacing presented in Table 3 the concentration of k in leaves woody and miscellaneous. Of *Eucalyptus*

Table 1 — Seasonal and annual estimates of litter fall at deferent spacing (g/$m^{-2}$) in 2014-15 *E. tereticornis*

| | Summer | | | | Rainy | | | | Winter | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaf | Woody | Miscellaneous | Mean | Leaf | Woody | Miscellaneous | Mean | Leaf | Woody | Miscellaneous | Mean | |
| 3×3 | 12.66 | 12.27 | 0.92 | 8.62 | 12.54 | 14.54 | 0.05 | 9.03 | 34.8 | 6.03 | 0.38 | 13.74 | 94.13 |
| 6×1.5 | 12.03 | 10.82 | 0.76 | 7.87 | 12.23 | 14.52 | 0.03 | 8.919 | 34.34 | 5.27 | 0.19 | 13.27 | 90.16 |
| 17×1×1 | 10.85 | 10.06 | 0.39 | 7.1 | 11.43 | 13.25 | 0.08 | 8.232 | 33.58 | 4.4 | 0.23 | 12.74 | 84.19 |
| Mean | 11.85 | 11.05 | 0.69 | 7.86 | 12.07 | 14.1 | 0.07 | 8.72 | 34.24 | 5.24 | 0.27 | 13.25 | 89.51 |
| Total | 70.79 | | | | 78.54 | | | | 119.26 | | | | 268.59 |

Table 2 — Seasonal and annual estimates of litter fall at deferent spacing (g/$m^{-2}$) in 2015-16 *E. tereticornis*

| | Summer | | | | Rainy | | | | Winter | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaf | Woody | Miscellaneous | Mean | Leaf | Woody | Miscellaneous | Mean | Leaf | Woody | Miscellaneous | Mean | |
| 3×3 | 13.45 | 12.52 | 1 | 8.99 | 13.15 | 14.99 | 0.05 | 9.38 | 34.8 | 6.15 | 0.44 | 13.8 | 96.51 |
| 6×1.5 | 12.43 | 11.4 | 0.91 | 8.87 | 12.34 | 15.77 | 0.03 | 8.91 | 34.76 | 5.48 | 0.25 | 13.39 | 93.15 |
| 17×1×1 | 11.19 | 10.39 | 0.43 | 7.34 | 11.72 | 13.55 | 0.1 | 8.23 | 33.83 | 4.61 | 0.3 | 12.92 | 84.93 |
| Mean | 12.36 | 11.44 | 0.78 | 8.195 | 12.4 | 14.77 | 0.03 | 9.06 | 34.47 | 5.41 | 0.33 | 13.37 | 91.53 |
| Total | 73.75 | | | | 81.54 | | | | 120.6 | | | | 275.59 |

Table 3 — Concentration of nutrient in litter falls at different spacing.

| | Leaf | | | | Woody | | | | Miscellaneous | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean |
| N | 0.91 | 0.92 | 0.93 | 0.92 | 0.41 | 0.41 | 0.42 | 0.42 | 0.368 | 0.37 | 0.378 | 0.372 |
| P | 0.13 | 0.14 | 0.15 | 0.13 | 0.13 | 0.14 | 0.16 | 0.13 | 0.108 | 0.112 | 0.116 | 0.112 |
| K | 0.47 | 0.46 | 0.45 | 0.46 | 0.33 | 0.33 | 0.33 | 0.33 | 0.416 | 0.418 | 0.422 | 0.419 |
| Ca | 0.96 | 0.97 | 0.99 | 0.97 | 0.95 | 0.96 | 0.96 | 0.96 | 0.926 | 0.928 | 0.932 | 0.929 |
| Mg | 0.56 | 0.57 | 0.58 | 0.57 | 0.55 | 0.55 | 0.55 | 0.55 | 0.524 | 0.526 | 0.534 | 0.528 |
| Cu | 13.52 | 13.54 | 13.78 | 13.61 | 13.70 | 13.63 | 13.52 | 13.62 | 10.884 | 11.024 | 11.024 | 10.977 |
| Zn | 138.27 | 137.87 | 137.84 | 137.99 | 110.45 | 110.67 | 110.92 | 110.68 | 125.736 | 125.776 | 126.086 | 125.866 |
| Mn | 269.96 | 270.46 | 230.83 | 257.08 | 183.84 | 184.03 | 184.37 | 184.08 | 171.006 | 171.264 | 171.668 | 171.313 |
| Fe | 366.60 | 366.81 | 367.21 | 366.87 | 440.41 | 440.71 | 441.48 | 440.87 | 127.778 | 127.836 | 128.138 | 127.917 |
| CD%5 spacing: NS<br>Nutrients: 7.634<br>A×B 13.223 | | | | | CD%5 spacing: NS<br>Nutrients :0.583<br>A×B: NS | | | | CD%5 spacing: NS<br>Nutrients :0.847<br>A×B: NS | | | |

plantation at spacing of 3×3 m was significantly more than the other two spacing.

Among leaves, the maximum calcium (0.99%) was recorded under 17×1×1 m spacing followed by 6×1.5 m. Among branches maximum concentration of calcium 0.96% was recorded in 17×1×1 m spacing followed by 6 × 1.5 m (0.94%) and minimum in 3×3 m spacing (0.92 The concentration of Mg in leaves, wood and miscellaneous grown at 17×1×1 m was maximum (0.58, 0.55 and 0.53% respectively), followed by 6×1.5 m (0.57, 0.55 and 0.56% respectively) and 3×3 m (0.57, 0.55 and 0.56% respectively) spacing. the concentration in all plant parts at 17×1×1 m spacing were significantly more than concentration at other two spacing and concentration at 6×1.5 m was more than 3×3 m spacing.

There were significant differences among the concentration of iron in wood and miscellaneous grown at different spacing. The concentration of copper at 17×1×1 m (441.48 ppm) was significantly more than the concentration at 6×1.5 (440.71 ppm) and 3×3 m (440.41 ppm) (Table 4). The concentration of iron showed somewhat different trends. The highest concentration of iron (228.13 ppm) was recorded in the miscellaneous of *Eucalyptus* grown at 17×1×1 m, which was at par with concentration at 6×1.5 m (227.83 ppm), but significantly more than at 3×3 m (227.77 ppm) (Table 4). The 17×1×1 spacing highest amount of P return (0.305 g /$m^{-2}$ $year^{-1}$) in next year (0.314 g /$m^{-2}$ $year^{-1}$) through leaf litter followed by 6×1.5 (0.289 g/$m^2$ $year^{-1}$), (0.302 g/$m^2$ $year^{-1}$) and minimum 3×3 spacing (0.296 g/$m^2$$year^{-1}$), (0.310 g/$m^2$ $year^{-1}$). However, biennial return of P through leaf fall in all the species was much lesser than those of other major nutrients (N, K, Ca and Mg). Ca return through leaf fall were highest in spacing 3×3 spacing (2.312 g/$m^{-2}$ $year^{-1}$) in next year (2.372 g/$m^{-2}$ $year^{-1}$) than 6×1.5 (2.259 g/$m^2$ $year^{-1}$), (2.304 g/$m^2$ $year^{-1}$) and minimum Ca was observed in 17×1×1 spacing (2.163 g/m2 $year^{-1}$), (2.204 g/m2 $year^{-1}$) for *E. tereticornis* (Table 4).

Table 4 — Amount of nutrient return through litter fall in plantation of different spacing.

2014-15

| | Leaf | | | | Woody | | | | Miscellaneous | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean |
| N | 2.16 | 2.188 | 2.056 | 2.14 | 0.53 | 0.51 | 0.47 | 0.51 | 0.019 | 0.014 | 0.009 | 0.014 |
| P | 0.296 | 0.289 | 0.305 | 0.30 | 0.17 | 0.16 | 0.16 | 0.16 | 0.006 | 0.004 | 0.003 | 0.004 |
| K | 1.136 | 1.094 | 1.035 | 1.09 | 0.45 | 0.42 | 0.38 | 0.42 | 0.022 | 0.016 | 0.011 | 0.016 |
| Ca | 2.312 | 2.259 | 2.16 | 2.24 | 1.25 | 1.17 | 1.07 | 1.16 | 0.049 | 0.035 | 0.023 | 0.036 |
| Mg | 1.336 | 1.313 | 1.304 | 1.32 | 0.72 | 0.68 | 0.61 | 0.67 | 0.027 | 0.020 | 0.014 | 0.020 |
| Cu* | 32.463 | 31.737 | 31.593 | 31.93 | 18.19 | 16.43 | 14.91 | 16.51 | 0.559 | 0.430 | 0.282 | 0.424 |
| Zn* | 331.40 | 320.603 | 309.944 | 320.65 | 145.55 | 135.11 | 122.80 | 134.49 | 6.548 | 4.815 | 3.177 | 4.847 |
| Mn* | 647.31 | 632.546 | 531.033 | 603.63 | 241.99 | 225.87 | 205.15 | 224.34 | 8.935 | 6.572 | 4.319 | 6.609 |
| Fe* | 878.89 | 858.392 | 823.308 | 853.53 | 578.75 | 539.18 | 489.26 | 535.73 | 6.649 | 4.898 | 3.234 | 4.927 |
| CD%5 spacing 13.904 | | | | | CD%5 spacing :0.559 | | | | CD%5 spacing :0.019 | | | |
| Nutrients: 24.082 | | | | | Nutrients :0.967 | | | | Nutrients :0.033 | | | |
| A×B 41.712 | | | | | A×B:1.676 | | | | A ×B: 0.057 | | | |

2015-16

| | Leaf | | | | Woody | | | | Miscellaneous | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean | 3×3 | 6×1.5 | 17×1×1 | Mean |
| N | 2.22 | 2.20 | 2.10 | 2.18 | 0.56 | 0.54 | 0.48 | 0.53 | 0.021 | 0.017 | 0.010 | 0.016 |
| P | 0.31 | 0.30 | 0.31 | 0.31 | 0.17 | 0.17 | 0.16 | 0.16 | 0.006 | 0.005 | 0.001 | 0.004 |
| K | 1.15 | 1.09 | 1.05 | 1.09 | 0.45 | 0.44 | 0.39 | 0.43 | 0.024 | 0.019 | 0.010 | 0.018 |
| Ca | 2.37 | 2.30 | 2.20 | 2.29 | 1.28 | 1.25 | 1.10 | 1.21 | 0.054 | 0.043 | 0.030 | 0.042 |
| Mg | 1.37 | 1.35 | 1.32 | 1.34 | 0.74 | 0.72 | 0.63 | 0.70 | 0.030 | 0.025 | 0.020 | 0.025 |
| Cu | 33.38 | 32.10 | 31.27 | 32.25 | 18.69 | 17.70 | 15.31 | 17.23 | 0.620 | 0.522 | 0.333 | 0.492 |
| Zn | 339.69 | 327.77 | 312.47 | 326.64 | 149.06 | 144.67 | 126.86 | 140.20 | 7.263 | 5.846 | 3.748 | 5.619 |
| Mn | 662.83 | 644.32 | 557.10 | 621.42 | 248.46 | 240.20 | 210.53 | 233.06 | 9.911 | 7.979 | 5.095 | 7.661 |
| Fe | 899.72 | 875.07 | 835.11 | 869.97 | 593.62 | 575.42 | 503.99 | 557.68 | 7.375 | 5.947 | 3.815 | 5.712 |
| CD%5 spacing 10.418 | | | | | CD%5 spacing :0.487 | | | | CD%5 spacing :0.022 | | | |
| Nutrients: 18.045 | | | | | Nutrients :0.843 | | | | Nutrients :0.029 | | | |
| A×B 31.254 | | | | | A×B:1.460 | | | | A×B: 0.067 | | | |

The amount of Mn return through leaf fall was highest in spacing 3×3 spacing (647.312 mg / $m^{-2}$ $year^{-1}$) in next year (662.832 mg/$m^{-2}$ $year^{-1}$) followed by 6×1.5 (632.546 mg/$m^2$ $year^{-1}$), (644.325 mg/$m^2$ $year^{-1}$) and minimum 17×1×1 spacing (531.033 $m^{-2}$ $year^{-1}$) in second year (557.102 mg/ $m^{-2}$ $year^{-1}$). The fall of woody and miscellaneous litters showed N annual returns of 0.48-0.56 mg/$m^2$ $year^{-1}$ and 0.021-0.010 mg/$m^2$ $year^{-1}$, respectively in 2016 (Table 4). Similar to leaf litterfall. The wood and miscellaneous litter fall also followed the same patterns of nutrient return; however, their amounts were considerably lower than those in leaf litter.

The maximum leaf litter production was at 3×3 m spacing in winter season followed by in 6×1.5 m in the year 2015 and 2016. The minimum leaf litter production was observed in 17×1×1 m. Wider spacing was found superior to accumulate the maximum amount of litterfall at minimum depth (0-30 cm). Rana *et al.*[18] also recorded higher litter production during winter and summer than in rainy season. It was found that the seasonal climate prevailing in this region has a profound influence on the pattern of leaf fall. Such seasonality may be attributed chiefly to the effect of a relatively dry period during winter months. Increase in litter production in broader spacing may be attributed to lesser competition for water and nutrients among the *Eucalyptus* trees. Secondly, at more extensive spacing tree capture more sunlight and spread its canopy as compared to closer spacing.

The concentration of N in leaves, woody and miscellaneous of eucalyptus plantation at the spacing of 17×1×1 m was significantly more than the other two spacing. The total concentration of nutrients (N, P, K) among different components decreased in order leaves > stems > branch. These results are in line with the findings of Lodhyal *et al*.[19]. Effect of spacing on micronutrients concentration (%) in different litter fall components of *Eucalyptus teretiocornis* based agroforestry system and are presented in Cu concentration was maximum in leaves followed by wood and miscellaneous. Mn concentration was maximum in leaves followed by wood and miscellaneous. N concentration was maximum in leaves followed by wood and miscellaneous[20]. Bhowmik[21] reported that litterfall and nutrient dynamics in soil under 20-year-old Eucalyptus hybrid plantation Data revealed that concentration of nitrogen decreased in summer season especially in the bark, wood and branch, while calcium showed an increasing trend in summer especially in leaf, twig, branch and timber. The maximum amount of all the nutrients was accumulated in the stem (bark + wood).

The concentration of Mn in leaves, woody and miscellaneous of eucalyptus plantation at a spacing of 17×1×1 m was significantly more than the other two spacing whereas, the concentration of Mn at 6×1.5 m spacing was significantly more 3×3 m spacing in both years. Fe concentration was maximum in leaves followed by wood and miscellaneous. The concentration of Fe in leaves, woody and miscellaneous of eucalyptus plantation at the spacing of 17×1×1 m was significantly more than the other two spacing whereas, the concentration of Fe, at 6×1.5 m spacing was significantly more 3×3 m spacing in both years. Rana *et al.*[22] corroborate his findings in general nutrient concentration in litter was in the order N> Ca> K>Mg> P> Fe>Mn >Zn >Cu. In total this research offers valuable details on the return to soil of litters fall-led soil nutrient to under North Indian Conditions.

## Conflict of Interests

Authors declare no conflict of interest

## Author Contributions

B K, S A and P K conceived of and designed the project; B K and S A supervised the study; T K, P K and D J wrote the paper and performed the analysis. P K checked and corrected the final draft. All authors read and approved the final manuscript.

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