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Estimation of the soil and plant nutrient budget of the traditional *Eucalyptus* based agroforestry system in different spacing

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Traditional tree-integrated farming systems are adopted for the security of food, fodder and fuelwood. Therefore, investigations were carried out to study the leaf litter, wood litter, miscellaneous litter and total litterfall in *Eucalyptus* based agri-silvicultural system. In this manuscript we observed that the leaf component was the main contributor to the total above-ground biomass in all the planting spacings followed by woody and miscellaneous. The major nutrient pool was in the leaves, and branches . Whereas, the total return of nutrients during both the years study period was in 6×1.5 m spacing returned the highest amount of N (54.04 kg/ha) through leaf litter followed by 3×3 m spacing (53.05 kg/ha), 17×1×1 m spacing (52.85 kg/ha) in 2014-15. Out of which the total amount of these nutrients used by the intercrops was 44.01 (kg/ha) of nitrogen, 9.96 (kg/ha) phosphorus and 68.65 (kg/ha) of potassium respectively. Hence, the remaining amount 45.31 (kg/ha) of nitrogen and 7.05 (kg/ha) of phosphorus. During seven and eighth year of *Eucalyptus* planted at 3×3 m spacing the farmers can take barley as an intercrop with the *Eucalypts terticornis* with a spacing of 3×3 m without adding any additional amount of nitrogen and phosphorus into the system. Hence can save some additional cost of fertilizer, which otherwise they have to add to raise intercrops with *Eucalyptus*.

Keywords: Eucalyptus, Litterfall, Nutrient, Spacings

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Expanding population is positioning unique demand for agriculture and to feed the expanding populationis a huge challenge for the agriculture sector[1]. The answer to the trouble is thru a mix of technological advancements and involvement of other purely natural ecosystems. The key good thing about agroforestry units is the improvement in full output by improving soil fertility[2]. Traditional tree-integrated farming systems are adopted for the security of food, fodder and fuelwood, but are unable to meet the requirement of the ever-increasing population. Agroforestry may be correct technological know-how in spots with fragile ecosystem and subsistence farming[3,4]. The tree absorbs nutrient from further root zone and returns nutrition as a result of litter tumble and root turnover into the subsurface, so encouraging in accumulating nutrition and improving upon soil actual physical attributes and nutrientuse efficiency in the system[5,6].

Litter tumble has a significant impact on soil development mainly because it is usually an essential ingredient during the circulation of mineral features and incorporates lots of elaborate natural and organic compounds, which change in organic degradability[7,8].

It was confirmed that the production potential of different agricultural crops under different spacings of poplar plantation and observed that the yield of all agricultural crops including cowpea and moong bean showed increased yield with a broader spacing of poplar plantation whereas decreased return with the increasing age of poplar plantation. Among all crops, during rainy seasons cowpea for fodder was found most compatible with poplar[9]. Moreover, the plant nutrient pool represented 20.2 to 23.0% (N and K) of the soil nutrient pool. In the trees, the primary nutrient pool was in stems, branches and roots. Crops accounted for 22 to 59% of the total uptake of nutrients by the plants. The annual return of nutrients (kg ha^{-1}) in litterfall and fine roots was: 95.96 N, 8.85 P, 48.08 and K 64.73[(ref. 10)].

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The pattern of release of nutrients from the decomposing litter was K>P>N. Rapid turnover of litter and fine roots favoured rapid intra system cycling the retention of nutrients in stems, branches and roots of trees. About 48 to 58% of N and K and 19 to 24% of P, Ca and Mg of the total nutrient uptake were lost from the system in crop harvest and fuel wood extraction. Eucalyptus plantation results in improvement in soil nutrient (N, P, K and organic matter) as compared to natural soil[11]. The nutrient return in litter fall and fine roots almost balanced the removal of nutrients in crop harvest excepting N and K. Thus the efficient use of nutrients from the soil pool and rapid intra-system cycling maintain high biological productivity of the agro forestry system. So the information in regards to the effect of eucalyptus on soil nutrient reserves at the same time as on soil natural and organic subject is vital to determine sustainable agro forestry techniques[12]. It is additionally very likely with the alterations in soil chemical houses, notably in soil natural and organic subject, vary soon after many eucalyptus rotations, different together with the soil variety and dominant local climate problems[13]. The aim of this paper is to judge the influence of various spacings of eucalyptus dependent agro forestry technique on soil chemical houses and nutrient position.

Materials and Methods

Experimental setup

The study was executed at the farm of Forestry Office, CCS Haryana Agricultural 'University, Hisar, Haryana, positioned at 290 10' N latitude and 750 40'E longitudes. The local climate on the review spot is semi-arid and primarily characterised by a scorching summertime. Previously recognized eight several years aged eucalyptus plantation planted at 3×3 m, 6×1.5 m and 17×1×1 m (paired row) spacings ended up utilized to have out the current investigation. Barley crop in rabi ended uplifted in an idealistic relationship with eucalyptus plantation together with the advisable cultural techniques underneath different spacings for the duration of your entire review interval. Four soil samples ended up gathered randomly underneath different spacings in a few replicates from a few depths (0-30, 30-60 and 60-90). No fertilization was supplied, and plantation was on the marginal land. Also, no phytosanitary measures were needed.

Litter collection, mineral content estimation and data analysis

The soil samples ended up taken ahead of sowing of crops various soil chemical properties available nutrients (nitrogen, phosphorus and potassium). Litter is usually the dried part of plants fallen on the ground. It was collected with the help of the litter trap. Litter traps were made of wooden frame (1.0×1.0 m), having a perforated bottom with steel mesh at its base. The size of the mesh was such that it holds the smallest portion. The depth of each trap was kept 30 cm. Twenty-four litter traps per hectare were placed randomly at 150 cm above the ground in all the treatments (6 boxes in each) for collecting different type of litter viz. leaf, branch, bark and, miscellaneous matter parts (flower, fruits etc.). The litter was collected since December 2014 from these traps at the one-month interval. The litter collection process was continued up to two years. The litter was sorted into different categories, and the samples of litter were dried in the oven; the dry weight was estimated with the aid of weighing balance.

Total nitrogen the soil was digested with concentrated H_2SO_4 in the presence of Hibbard's mixture and after that total N was estimated by distillation on a Kjeldahl assembly[14]. The distillation was carried out using 45% NaOH and ammonia was absorbed in a known volume of 0.1N H_2SO_4. The percentage of nitrogen was calculated from the volume of 0.1N H_2SO_4 used for the absorption of ammonia which was known by titrating the excess H_2SO_4 against a standard alkali using methyl red indicator. For the overall phosphorus, the litter was digested with 20 mL of triacid combination (HNO_3:$HClO_4$: H_2SO_4 while in the ratio of nine:four:one). The contents ended up heated right up until quantity was diminished to 3-5 mL. The completion of digestion was verified when liquid turned colourless. The amount was then manufactured up to 100 mL with distilled water. Digested extract (20 mL) was taken in 50 mL volumetric flask also to it ten ml of ammonium molybdate vanadate resolution was included. Soon after complete mixing, the quantity was manufactured upto 50 mL with distilled water and combination permitted to stand for 30 min for blue colour growth. The colour was then read through at 470 nm on spectrophotometer[15]. The estimation of overall potassium was firm according to the tactic presented by Henway and Heidal[16]. The processed plant sample was taken in a 100 mL plastic bottle. To it was included 20-5 mL ammonium acetate resolution which was shaken on an electric-powered shaker for 5 min. The suspension was filtered on Whatman No. filter paper. The looking through on the filtrate was taken on flame photometer soon after changing the instrument to a hundred with fifty or a hundred ppm K resolution.

The total biomass Agricultural intercrop was calculated, adding biomass of all the crop components (above ground) of intercrops during the study year.To estimate the biological yield of crops plants were uprooted to the depth possible in 1×1 m area. Fresh weight above and below ground parts was taken with the electronic help balance. After that, the representative samples, from all treatments and replications, were taken and brought to the laboratory and dried in the oven at 60^0C till the constant weight to record dry weight. The biological yield was calculated using following formula:

$$\text{Biomass of branch\textbackslash leaves} = \frac{\text{Dry weight of sample}}{\text{fresh weight branch\textbackslash leaves}} \times \text{Total Fresh weight}$$

Nutrient status of plant parts was estimated by taking samples of leaves, wood and miscellaneous, analyzing for macronutrients (N, P and K). Nutrient concentration was multiplied by the weight of annual litterfall to compute the amounts of nutrients returned to the soil.The replicated data of all the characters recorded were analyzed statistically using model suggested by Panse and Sukhatme (1989) using. For the data analysis, we have used the Statgraphics Centurion version 18.

Results

The maximum leaf litter production (6001.43 kg/ha) was at 3×3 m spacing in 2014-2015 followed by wood litter (3285.45 kg/ha) and minimum (152.22) in the miscellaneous litter (Fig. 1).

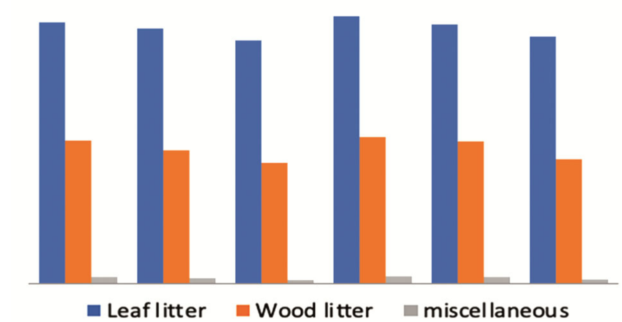


Fig. 1 — Effect of different spacing of litter (kg/ha) components in *E. tereticornis* based agroforestry system.

Effect of spacing on macronutrients Nitrogen concentration (%) in different litter fall components of *E. tereticornis* based agroforestry system. The concentration of nitrogen in different plant parts of *Eucalyptus* grown in different spacing presented in Fig. 2. The concentration of N in leaves, woody parts and miscellaneous matter of *Eucalyptus* plantation at a spacing of 17×1×1 m was significantly more than the other two spacing whereas, the concentration of N at 6×1.5 m spacing was substantially more than 3×3 m spacing during both the years.

Among leaves, the maximum nitrogen (0.946%) was recorded under 17×1×1 m spacing followed by 6×1.5 m and 3×3 m. Among woody parts,the maximum concentration of nitrogen (0.494%) was recorded in 17×1×1 m spacing followed by 6×1.5 m (0.412%) and minimum in 3×3 m spacing (0.356%) in the year 2014-15. Among leaves the maximum nitrogen (0.986 %) was recorded under 17×1×1 m spacing followed by 6×1.5 m (0.932%). Among woody parts maximum concentration of nitrogen (0.520%) was recorded in 17×1×1 m spacing followed by 6×1.5 m (0.432%) and minimum in 3×3 m spacing (0.364%). Likewise, highest concentration of nitrogen was recorded in 17×1×1 m spacing in the miscellaneous matter (0.472%, respectively), followed by 6×1.5 m spacing (0.380%, respectively) and minimum in 3×3 m spacing (0.342%, respectively) during 2015-16. The data regarding phosphorus concentration in different plant parts are presented in Fig. 3.

In the year 2014-15, data among all the treatment was found statistically different during the year 2015-16. The highest concentration was found in leaves (0.152%) at 17×1×1 m spacing followed by leaves (0.130%) at 6 ×1.5 m spacing. Like N, P and K concentration at spacing, i.e., 17×1×1 m was significantly more than the other two spacing. The

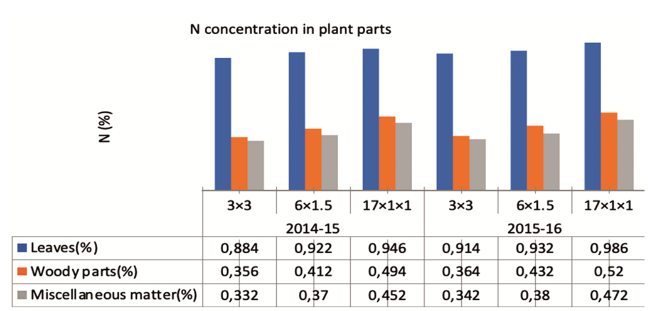
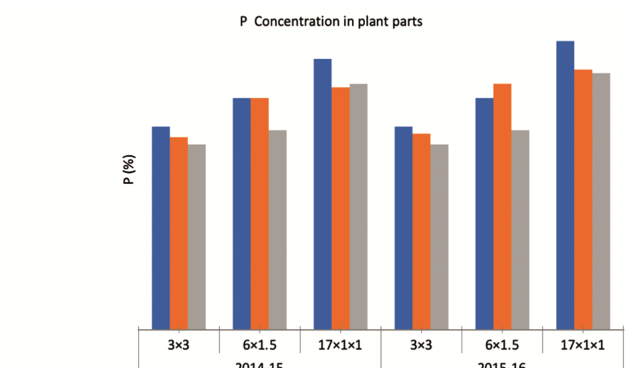


Fig. 2 — Effect of spacing on macronutrients N concentration (%) in different litter fall components of *E. tereticornis* based agroforestry system.

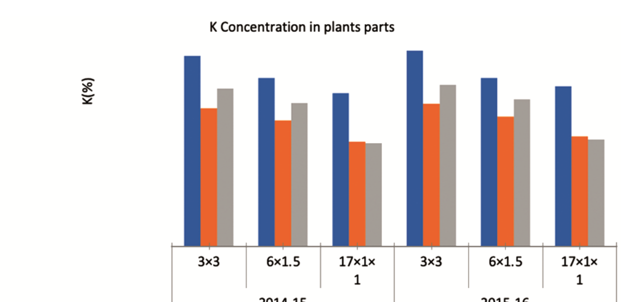
concentration of potassium in different plant parts of *Eucalyptus* grown in different spacing is shown in Fig. 4. It was found at par for woody parts and miscellaneous matter components in both the years. However, the concentration of P in 3×3 m spacing was found to be significantly more than 6×1.5 m. Among leaves, the maximum potassium (0.50%) was recorded under 3×3 m spacing followed by 6×1.5 m. Among woody parts maximum concentration of potassium (0.364%) was recorded in 3×3 m spacing followed by 6×1.5 m (0.332%) and minimum in 17×1×1 m spacing (0.276%). Likewise, highest concentration of K in differentmatter litter under 3×3 m spacing (0.416%) followed by 6×1.5 m spacing (0.378%) and minimum in 17×1×1 m spacing (0.272%) during 2014-15. In 2015-16 among leaves the maximum potassium (0.516%) was recorded under 3×3 m spacing followed by 6×1.5 m spacing.

Among woody parts,themaximum concentration of Potassium 0.376% was recorded in 3×3 m spacing followed by 6×1.5 m (0.342%) and minimum in 17×1×1 m spacing (0.290%). Likewise, the highest concentration of K in the miscellaneous matter under 3×3 m spacing (0.426%) of miscellaneous matter followed by 6×1.5 m spacing (0.388%) and minimum in 17×1×1 m spacing (0.282%). The concentration of N, P and K was maximum in leaves followed by woody parts and miscellaneous matter at all the spacing.



	3×3 (2014-15)	6×1.5 (2014-15)	17×1×1 (2014-15)	3×3 (2015-16)	6×1.5 (2015-16)	17×1×1 (2015-16)
Leaves (%)	0,114	0,13	0,152	0,114	0,13	0,162
Woody parts (%)	0,108	0,13	0,136	0,11	0,138	0,146
Miscellaneous (%)	0,104	0,112	0,138	0,104	0,112	0,144

Fig. 3 — Effect of spacing P concentration (%) in different litter fall components of *E. tereticornis* based agroforestry system.



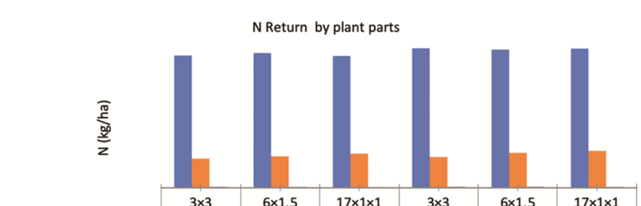
	3×3 (2014-15)	6×1.5 (2014-15)	17×1×1 (2014-15)	3×3 (2015-16)	6×1.5 (2015-16)	17×1×1 (2015-16)
Leaves(%)	0,502	0,444	0,404	0,516	0,444	0,422
Woody parts(%)	0,364	0,332	0,276	0,376	0,342	0,29
Miscellaneous matter(%)	0,416	0,378	0,272	0,426	0,388	0,282

Fig. 4 — Effect of spacing K concentration (%) in different litter fall components of *E. tereticornis* based agroforestry system

Nutrients return by litter at different spacing

Weights of nutrients returned through annual litterfall are given in 6×1.5 m spacing yielded the highest amount of N (54.04 kg/ha) through leaf litter followed by 3×3 m spacing (53.05 kg/ha), 17×1×1 m spacing (52.85 kg/ha) in 2014-15. In the next year (2015-16) same as data was observed showed that highest amount of N returned in 3×3 m spacing (55.92 kg/ha), 6×1.5 m spacing (55.44 kg/ha), 17×1×1 m spacing (55.83 kg/ha). However, 17×1×1 m spacing returned the highest amount of N (13.6 kg/ha) through woody parts followed by 6×1.5 m (12.6 kg/ha) and at 3×3 m (11.6 kg/ha), in 2014-15. In the next year (2015-16) observed same data showed that highest amount of N returned in 17×1×1 m (14.8 kg/ha) followed by spacing (13.9 kg/ha), 3×3 m spacing (12.3 kg/ha). However, 3×3 m spacing (0.50 kg/ha) followed by 6×1.5 m spacing (0.45 kg/ha) and 17×1×1 m spacing (0.38 kg/ha) spacing returned the highest amount of N (13.6 kg/ha) through miscellaneous matter in 2014-15. In the next year (2015-16) same observed data was showed that most elevated amount of N returned in 6×1.5 m spacing (0.58 kg/ha) followed by 3x 3 m spacing (0.56 kg/ha) and 17×1×1 m spacing (0.44 kg/ha). It was also found at par for (3×3 and 6×1.5 m) and (6×1.5 and 17×1×1 m) spacing in both the years (Fig. 5).

The 17×1×1 m spacing showed highest amount of P return (8.49 kg/ha) in next year (8.97 kg/ha) through leaf litter followed by 6×1.5 m spacing having most



	3×3 (2014-15)	6×1.5 (2014-15)	17×1×1 (2014-15)	3×3 (2015-16)	6×1.5 (2015-16)	17×1×1 (2015-16)
Leaves (kg/ha)	53,05	54,04	52,85	55,92	55,44	55,83
Woody(kg/ha)	11,69	12,61	13,69	12,35	13,99	14,81
Miscellaneous(kg/ha)	0,5	0,45	0,38	0,56	0,58	0,44

Fig. 5 The amount of N return (kg/ha) through litterfall in the plantation of different spacing 2014-15 and 2015-16.

elevated amount of P return (3.98 and 4.41 kg/ha) followed by 17×1×1 m spacing(3.77 and 4.07 kg/ha) and minimum 3×3 m spacing (3.54 and 3.72 kg/ha) and through miscellaneous matter the 17×1×1 m spacing highest amount of P return (12.38 kg/ha) in next year (13.18 kg/ha) through miscellaneous matter followed by 6×1.5 m spacing having most elevated amount of P return (11.74 and 12.40 kg/ha) and minimum 3×3 m spacing (10.54 and 11.11 kg/ha). However, the biennial performance of P through leaf fall in all the species was far less than those of other significantnutrients (N, K, Ca and Mg). It was also found at par for (6×1.5 and 17×1×1 m) spacing in both the years(Fig. 6).

The amount of potassium return through leaf fall was highest in spacing 3×3 m spacing (30.12 kg/ha) in next year (31.76 kg/ha) followed by 6×1.5 m (26.02 kg/ha), (26.70 kg/ha) and minimum 17×1×1 m spacing (22.57 kg/ha) in second year (23.84 kg/ha).

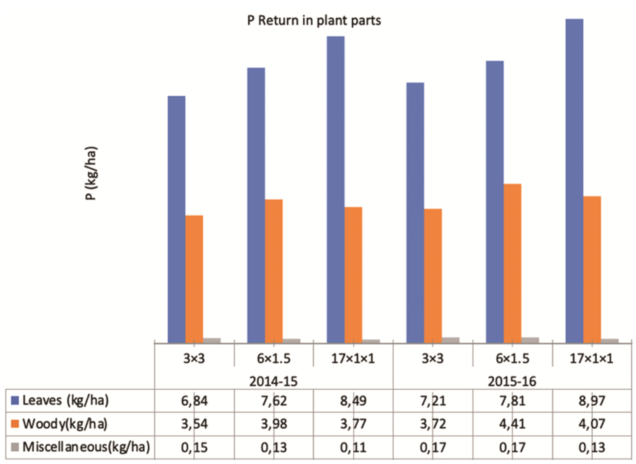


Fig. 6 — The Amount of P return (kg/ha) through litterfall in plantation of different spacing 2014-15 and 2015-16.

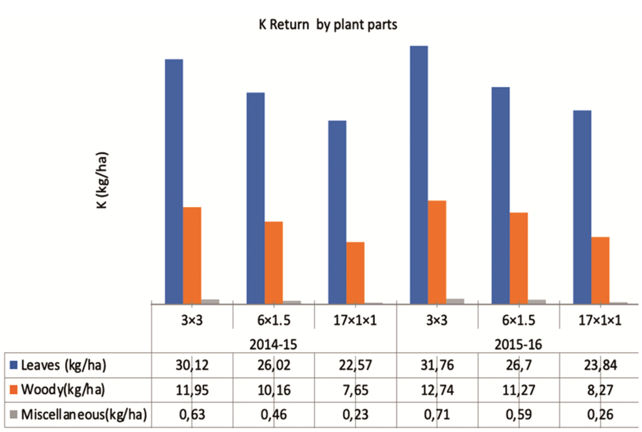


Fig. 7 — The Amount of K return (kg/ha) through litterfall in the plantation of different spacing 2014-15 and 2015-16.

However, through woody parts it was highest in spacing 3×3 m spacing (11.95 kg/ha) in next year (12.74 kg/ha) followed by 6×1.5 m (10.16 and 11.27 kg/ha) and minimum 17×1×1 m spacing (7.65 kg/ha) in second year (8.27 kg/ha) and through miscellaneous matter it was highest in 3×3 m spacing (0.63 kg/ha) in next year (0.71 kg/ha) followed by 6×1.5 m (0.46 and 0.59 kg/ha) and minimum at 17×1×1 m spacing (0.23 kg/ha) in the second year (0.26 kg/ha) (Fig. 7).

Intercrop biomass indicates that the maximum total crop biomass (5642.76 kg/ha) was recorded in 17×1×1 m spacing followed by 6×1.5 m spacing (4408.84 kg/ha), and minimum was reported (3083.56 kg/m^2) from 3×3 m spacing in 2015 and maximum total crop biomass (5444.06 kg/ha) was recorded in 17×1×1 m spacing followed by 6×1.5 m spacing (4262.08 kg/ha), and minimum was reported (3253.08 kg/m^2) from 3×3 m spacing in the next year 2016. It was observed that the total intercropped biomass found at par in 2015 and 2016 (Table 1).

NPK content

The concentration of nitrogen in the total biomass of barley crop grown at different spacing is presented in (Table 2). The frequency of N in 17×1×1 m spacing was significantly higher (0.78 %) than in 6×1.5 m

Table 1 — Total intercropped biomass of barley crop at the different spacing of *E. tereticornis* based agroforestry system during rabi 2015 and rabi 2016

Total biomass of barley crop in three spacing (kg/ha)			
Spacing(m)	2015	2016	Mean
3×3	3083.56	3422.60	3253.08
6×1.5	4408.84	4115.32	4262.08
17×1×1	5642.76	5245.36	5444.06
Mean	4378.38	4261.09	4319.74

Table 2 — Nutrients (N, P and K) concentration in barley intercrop at different spacing

N, P and K (%) concentration in barley crop in 2015			
Spacing(m)	N	P	K
3×3	0.64	0.11	1.06
6×1.5	0.68	0.13	1.10
17×1×1	0.78	0.17	1.21
CD at 5%	0.05	0.04	0.09
N, P and K (%) concentration in barley crop in 2016			
Spacing(m)	N	P	K
3×3	0.65	0.15	1.15
6×1.5	0.70	0.17	1.19
17×1×1	0.73	0.19	1.28
CD at 5%	0.05	0.02	0.09

spacing (0.68%) and 3×3 m spacing (0.64%) in 2015. In next year also the same trend in N concentration was recorded in 17×1×1 m spacing (0.73%), 6×1.5 m (0.70%) and minimum were recorded in 3× 3 m spacing (0.65 %) during 2016. It was found at par for 3×3 and 6×1.5 m in both the years, and it was also found at par for 6×1.5 and 17×1×1 m in 2016.

Maximum P concentration in barley crop was observed in 17×1×1 m spacing (0.17 %) followed by 6×1.5 m spacing (0.13%) and minimum concentration in 3×3 m spacing (0.11%) in 2015. In the second year, data was also recorded the same trend that maximum concentration of P was in 17×1×1 m spacing (0.19%) followed by 6×1.5 m spacing (0.17%) and minimum concentration was in 3×3 m spacing (0.15 %) in 2016. It was found at par for 3×3 and 6×1.5 m in 2015 and 6×1.5 and 17×1 ×1 m in 2016 (Table 2).

The concentration of potassium in different spacing in barley crop was observed the maximum in 17×1×1 m spacing (1.21%) followed by 6×1.5 m spacing (1.10%) and minimum concentration in 3×3 m spacing (1.06%) in 2015. In second year data was also recorded that maximum concentration of K was in 17 ×1×1 m spacing (1.28%) followed by 6×1.5 m spacing (1.19%) and minimum concentration in 3×3 m spacing (1.15%) in 2016. It was found at par for 3×3 and 6×1.5 m in both the years and it was also found at par for 6×1.5 and 17× 1 ×1 m in 2016 (Table 2).

Nutrients output by barley crop

Nitrogendata in showed that in barley crop the N concentration output was maximum in 17×1×1 m spacing (36.49 kg/ha) followed by 6×1.5 m spacing (29.98 kg/ha) and minimum concentration in 3×3 m spacing (24.05 kg/ha) during 2015. In the second year, a maximum level of N was in 17×1×1 m spacing (38.46 kg/ha) followed by 6×1.5 m spacing (28.94 kg/ha) and minimum concentration in 3×3 m spacing (22.24 kg/ha) in 2016. The maximum level of Phosphorus through barley crop was recorded in 17×1×1 m spacing (6.39 g/m^2) followed by 6×1.5 m spacing (6.02 kg/ha) and minimum concentration in 3×3 m spacing (5.44 kg/ha) during 2015. In the second year, the maximum concentration of P was recorded that in 17×1×1 m spacing (8.04 kg/ha) followed by 6×1.5 m spacing (7.27 kg/ha) and minimum concentration in 3×3 m spacing (6.73 kg/ha) in 2016 (Table 3).

The maximum concentration of Potassium through barley crop was recorded in 17×1×1 m spacing (59.81 kg/ha) followed by 6×1.5 m spacing (48.49 kg/ha) and minimum concentration in 3×3 m spacing (37.51 kg/ha) during 2015. In the second year, data was also recorded that maximum concentration of K was in 17×1×1 m spacing (67.14 kg/ha) followed by 6×1.5 m spacing (48.97 kg/ha) and minimum concentration in 3×3 m spacing (39.47 kg/ha) in 2016. It was found at par for 3×3 and 6 ×1.5 m in 2016 (Table 3).

The Nutrient budget under various spacing of *Eucalyptus* based agroforestry system. The higher nitrogen was added by 6×1.5 m spacing (67.11 kg/ha) followed by 17×1×1 spacing (66.93 kg/ha) and minimum added nitrogen in 3×3 m spacing (65.25 kg/ha). Nitrogen uptake was higher 17×1×1 m (44.01 kg/ha) followed by spacing 6×1.5 m (29.98 kg/ha) and 3×3 m spacing (19.94 kg/ha). The maximum nitrogen balance was in 3×3 m spacing (45.31 kg/ha) followed by 6×1.5 m spacing (37.13 kg/ha) and 17×1×1 m spacing (22.91 kg/ha) in 2015. In the next year 2016 maximum nitrogen was added in 17×1×1 m spacing (71.09 kg/ha) followed by 6×1.5 m spacing (70.02 kg/ha) and minimum added nitrogen in 3×3 m spacing (68.85 g/m^2). Nitrogen uptake was higher in spacing 3×3 m (38.46 kg/ha) followed by 6×1.5 m (28.94 kg/ha) and 17×1×1 m (22.24 kg/ha) respectively. The maximum nitrogen balance in 3×3 m spacing (46.60g/m^2) followed by 6×1.5 m spacing (41.07 kg/ha) and 17×1×1 m spacing (32.62 kg/ha).The higher phosphorus was added in 17×1×1 m spacing (12.38 kg/ha) followed by 6×1.5 m spacing (11.72 kg/ha) and minimum added phosphorus in 3×3 m spacing (10.54 kg/ha). Phosphorus uptake 17×1×1 m spacing (9.96 kg/ha) followed by 6×1.5 m spacing (6.02 kg/ha) and 3×3 m (3.49 kg/ha). The maximum phosphorus balance was in 3×3 m spacing

Table 3 — Amount of nutrients return through barley in different spacing

N, P and K (kg/ha)output by barley crop in 2015			
Spacing(m)	N	P	K
3×3	24.05	5.44	37.51
6×1.5	29.98	6.02	48.49
17×1×1	36.49	6.39	59.81
CD at 5%	2.02	NS	4.04
N, P and K (kg/ha) output by barley crop in 2016			
Spacing(m)	N	P	K
3×3	22.24	6.73	39.47
6×1.5	28.94	7.27	48.97
17×1×1	38.46	8.04	67.14
CD at 5%	4.76	0.74	7.79

Table 4 — Nutrient budget (kg/ha) under various spacing of *Eucalyptus* based agroforestry system in 2015 and 2016

Year 2015				Spacing					
		3×3 (m)			6×1.5 (m)			17×1×1 (m)	
Nutrient	Added	Uptake	Balance	Added	Uptake	Balance	Added	Uptake	Balance
N	65.25	19.94	45.31	67.11	29.98	37.13	66.93	44.01	22.91
P	10.54	3.49	7.05	11.73	6.02	5.71	12.38	9.96	2.41
K	42.70	32.68	10.01	36.65	48.49	-11.84	30.45	68.65	-38.19
Year 2016		3×3 (m)			6×1.5 (m)			17×1×1 (m)	
Nutrient	Added	Uptake	Balance	Added	Uptake	Balance	Added	Uptake	Balance
N	68.85	22.24	46.60	70.02	28.94	41.07	71.09	38.46	32.62
P	11.11	6.73	4.38	12.48	7.27	5.13	13.18	8.04	5.14
K	45.21	39.44	5.74	38.57	48.97	-10.41	32.38	67.14	-34.75

(7.05 kg/ha) followed by 6×1.5 m spacing (5.71 kg/ha) and 17×1×1 m spacing (2.41 kg/ha) in 2015. In the year 2016, maximum phosphorus added in 17×1×1 m (13.18 kg/ha) followed by 6×1.5m spacing (12.40 kg/ha) and 3×3 m (11.11 kg/ha) and maximum uptake of phosphorus was in 17×1×1 m spacing (8.04 kg/ha) followed by 6×1.5 m spacing (7.27 kg/ha) and 3×3 m spacing (6.73 kg/ha). However, maximum phosphorus balance was in 17×1×1 m spacing (5.14 kg/ha) followed by 6×1.5 m spacing (5.13 kg/ha) and 3×3 m spacing (4.38 kg/ha) (Table 4).

The higher potassium added was in 17×1×1 m spacing (42.70 kg/ha) followed by 6×1.5 m spacing (36.65 kg/ha) and minimum added potassium was in 3×3 m spacing (30.45 kg/ha). The same trend was followed in the uptake of potassium viz., higher potassium uptake was in 17×1×1 m spacing (68.65 kg/ha) followed by 6×1.5 m spacing (48.49 kg/ha)and 3×3 m spacing (32.68 kg/ha). The maximum potassium balance was in 3×3 m spacing (10.01 kg/ha) followed by 6×1.5 m spacing (-11.84 kg/ha) and 17×1×1 m spacing (-38.19 kg/ha) in the year 2015. In the year 2016, maximum potassium was added in 3×3 m (45.21 kg/ha) followed by 6×1.5 m spacing (38.57 kg/ha) and 3×3 m spacing (32.38 kg/ha) and maximum uptake of potassium is by 17×1×1 m spacing (67.14 kg/ha) followed by 6×1.5 m spacing (48.97 kg/ha) and 3×3 m spacing (39.47 kg/ha). However, maximum potassium balance in 3×3 m spacing (5.74 kg/ha) followed by 6×1.5 m spacing (-10.40 kg/ha) and 17×1×1 m spacing (-34.75 kg/ha) (Table 4).

Discussion

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 higher nutrient status under closer spacings on the addition of a massive amount of leaf litter. The upper decomposition of leaf litter favours' the top nutrient position on the soil. Related conclusions ended up also noticed by a similar study in poplar[17].

The upper offered nutrient articles in agroforestry technique above the agriculture technique may be attributed to litter-fall addition from trees at the same time as the addition of root residues of crops and trees. These conclusions ended up supported by other studies[18–21]. The account of recycling of natural and organic subject increased natural and organic carbon and offered N, P and K contents ended up noticed while in the soil underneath intercropped eucalyptus plantations than in remote site with no trees along with the contents assorted relying on the intercrops. The effect of agroforestry programs on soil fertility regarding increased natural and organic subject articles, overall nitrogen, offered phosphorus and potash while in the prime soil has become described by Rizvi *et al.*[22].

The concentration of Nitrogen in leaves, woody parts and miscellaneous matter components of litter falls of *Eucalyptus* plantation at 17×1×1 m spacing was significantly more than the other two spacing whereas the concentration of N at 6×1.5 m spacing was considerably more than 3×3 m spacing during both the years. Similarly, Phosphors concentration in leaves, woody parts and miscellaneous matter type of litter of *Eucalyptus* plantation at, i.e., 17×1×1 m spacing was significantly more than the other two spacing while in 6 ×1.5 m spacing, it was substantially more at 3×3 m spacing and minimum P concentration in leaves of *Eucalyptus* was recorded at 3×3 m spacing, which was significantly less than the other two spacing during both the years. The concentration of potassium in leaves, woody parts and miscellaneous matter of *Eucalyptus* plantation at of 3×3 m spacing was significantly more than the other two spacing, whereas the concentration of K at 6×1.5 m spacing was significantly more than 17×1×1 m spacing and significantly less than 3×3 m spacing. The total concentration of nutrients (N, P and K) among different components decreased in order leaves > woody > miscellaneous. Maximum nutrient concentration was present in leaves because the leaves are a metabolically most active component of the tree and it coordinated with the findings of Lodhyal *et al.*[23]and Rana *et al.*[24].

Nutrient Return by Above Ground Litter Production at Different Spacing. Nitrogen concentration was maximum in leaves followed by woody parts and miscellaneous matter. The concentration of N in leaves woody parts and miscellaneous matter of *Eucalyptus* plantation at spacing of 6×1.5 m was significantly more than the other two spacing, whereas the concentration of N at 17×1×1 m spacing was substantially more than 3×3 m spacing in both years. Phosphorus concentration was maximum in leaves followed by woody parts and miscellaneous matter. The concentration of P in leaves woody parts and miscellaneous matter of *Eucalyptus* plantation at spacing of 6×1.5 m was significantly more than the other two spacing, whereas the concentration of P at 17×1×1 m spacing was considerably more than 3×3 m spacing in both the years.Potassium concentration was maximum in leaves followed by woody parts and miscellaneous matter. The concentration of K in leaves, woody parts and miscellaneous matter of *Eucalyptus* plantation at spacing of 3×3 m was significantly more than the other two spacing, whereas the concentration of P at 3×3 m spacing was significantly more 17×1×1 m spacing in both the years. Similar results were reported by Rana *et al.*[25] reported that nutrient concentration in litter was in the order N> K> P>. In all the four species of the study, nutrient concentration was more significant in leaf litter than the other litter components the share of macronutrients (N, P, K and Ca) in leaf litter was significantly more than Woody parts litter and miscellaneous matter litter. The maximum total crop biomass (5642.76 kg/ha and 5444.06 kg/ha) was recorded in 17×1×1 m spacing followed by 6×1.5 m spacing (4408.84kg/ha and 4262.08 kg/ha) and was minimum reported (3083.56 kg/ha and 3253.08 kg/ha) from 3×3 m spacing in 2015 and in the next year 2016, respectively.

The narrow tree spacing allowed significantly lower yield of barley as compared with all other agroforestry systems with wider row spacing for trees. The broadest paired row 17×1×1 treatment produced the highest yield in the present study as compared to the additional two spacing. Similar results were reported by Fikreyesus *et al.*[26] who reported that water use of the system increased up to a distance of 6 m from the tree line that causes moisture stress to the crop.

Apart from nutrient and moisture, light is a major limiting factor for crop growth and yield under tree species. Being an evergreen tree species, *Eucalyptus* reduced light availability and decreased crop yield. Nutrients concentration (N, P and K) at different spacing of barley crops. The concentration of N, P and K in 17×1×1 m spacings were significantly maximum followed by in 6×1.5 m spacing and 3×3 m spacing in 2014-15 and 2015-16, respectively. Similarly Bisht *et al.*[27] indicated that higher organic matter and nutrients (NPK) were found under canopy cover than in the open. N, P and K concentration in barley crop through the output was observed the maximum in 17×1×1 m spacing followed by 6×1.5 m spacing and minimum concentration was observed in 3×3 m spacing in 2014-15 and 21015-16. The higher N, P and K were added in 6×1.5 m spacing followed by 17×1×1 m spacing and minimum added nitrogen was in 3×3 m spacing. N, P and K uptake 17×1×1 m, 6×1.5 m and 3×3 m respectively. The maximum N, P and K balance were in 3×3 m spacing followed by 6×1.5 m spacing and 17×1×1 m spacing in 2014-15 and 2015-16.

Conclusion

The maximum N, P and K were added in 6×1.5 m spacing followed by 17×1×1 m spacing and minimum added nitrogen was in 3×3 m spacing. N, P and K uptake 17×1×1 m, 6×1.5 m and 3×3 m, respectively. The maximum N, P and K balance was in 3×3 m spacing followed by 6×1.5 m spacing and 17×1×1 m spacing. The major nutrient pool was recorded in leaves, branches and miscellaneous matter types of litter. The total amount of litter production (for all parts of the tree) in 3×3 m spacing of *Eucalyptus* was more than seven tones/ha. The total return of nutrients during both the years study period was of 134.10 (kg/ha) Nitrogen, 21.65 (kg/ha) Phosphors and 87.91 (kg/ha) potassium. Out of which the total amount of these nutrients used by the intercrops was 42.18 (kg/ha) of nitrogen, 10.22 (kg/ha) phosphorus and 72.12 (kg/ha) of potassium. Which was ultimately left unused in the soil during seven and eighth year of *Eucalyptus* planted at 3×3 m spacing the farmers can take barley as an intercrop with the *Eucalypts terticornis* planted at a spacing of 3×3 m without adding any additional amount of nitrogen and phosphorus into the system.

Conflict of Interest

Authors have 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. P K checked and corrected the final draft. All authors read and approved the final manuscript.

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