**Nutrient and litter dynamics in Cowpea + Pongamia agroforestry system**

**ABSTRACT**

Agroforestry systems offer sustainable solutions for enhancing soil fertility, improving crop productivity and maintaining ecological balance. Litter production and decomposition play a significant role in nutrient cycling and soil fertility enhancement within agroforestry systems. The study was conducted in the ‘M’ block of AICRP on Agroforestry unit, ZARS, UAS, GKVK, Bangalore, during January 2022 to June 2022. This study investigates the nutrient and litter dynamics in a cowpea (Vigna unguiculata) + Pongamia (Pongamia pinnata) agroforestry system under semi-arid conditions. Key parameters such as litterfall quantity, decomposition rate, nutrient release patterns, and soil nutrient status were analyzed before crop sown and after harvest of the crop in cowpea + Pongamia agroforestry system. The results revealed that litterfall production followed unimodel pattern and distinct peak was observed in February month in all the germplasms. RAK-2015-10, have recorded the highest and mean accumulation of litterfall in the month of February and lowest litterfall production was noticed in June month. Whereas, the lowest mean accumulation and total accumulation of litterfall was observed in RAK-2015-09. The results also noticed that the interaction of RAK-2015-10 germplasm and cowpea has significantly enhanced nitrogen input through biological fixation, while Pongamia contributed substantially to organic matter and macro-nutrient cycling via litterfall. Litter decomposition showed a steady nutrient release pattern, positively influencing soil fertility and supporting the growth of intercrops. The synergistic interaction between tree and legume components in the system demonstrated improved nutrient use efficiency and long-term sustainability. Expanding the cultivation of cowpea under RAK-2015-10 germplasm can significantly improve the soil fertility and productivity under agroforestry system.

**INTRODUCTION**

Agroforestry systems integrate trees with agricultural crops and/or livestock; offer a sustainable land-use strategy that enhances soil fertility, biodiversity and productivity, especially in tropical and semi-arid regions (Nair, 2011 & Jose, 2009). Agroforestry systems facilitate complex ecological interactions between the different components and promotes nutrient recycling, microclimate regulation and erosion control. Among the tree species suitable for agroforestry, *Pongamia pinnata* (syn. *Millettia pinnata*), a deep-rooted, nitrogen-fixing leguminous tree, has garnered significant attention due to its multipurpose use in bio-pesticides, green manure, reforestation and biofuel production (Scott et al., 2008).

Cowpea (*Vigna unguiculata*), a short-duration legume widely cultivated in semi-arid regions, is well suited for intercropping due to its drought tolerance, nitrogen-fixing ability and ability to improve soil structure and organic matter content (Singh et al., 1997). Integrating cowpea with *Pongamia* not only maximizes land use efficiency but also potentially enhances nutrient cycling and soil health through increased litter inputs and below-ground interactions..

Litter dynamics comprises litterfall, decomposition and nutrient release which are fundamental processes in agroforestry systems, significantly influencing soil nutrient availability and organic matter buildup (Palm et al., 2001). Tree and crop residues contribute to the formation of a biologically active soil layer, which supports microbial activity and improves soil structure. The quality and quantity of litter, along with climatic and edaphic factors, govern decomposition rates and the subsequent release of essential nutrients such as nitrogen (N), phosphorus (P) and potassium (K) (Giller, 2001). Nutrient dynamics, encompassing the uptake, transformation and movement of nutrients within the system, are closely linked to litter decomposition and root-soil interactions. Optimizing these dynamics is significant for maintaining soil fertility and achieving sustainable yields in agroforestry-based production systems..

Despite the ecological importance of nutrient and litter dynamics, there is a paucity of integrated studies focusing on these processes in cowpea-based *Pongamia* agroforestry systems, particularly under rainfed and semi-arid conditions. Understanding how tree–crop interactions influence nutrient availability and litter turnover is essential for designing productive and sustainable land management practices. Therefore, the present study aims to evaluate both nutrient cycling and litter dynamics in a cowpea + Pongamia agroforestry system..

**MATERIAL AND METHODS**

The present study entitled “Nutrient and litter dynamics in Cowpea + Pongamia agroforestry system” was carried out at ‘M’ block, in All India Coordinated Research Project(AICRP) on Agroforestry unit, Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vigyana Kendra (GKVK), University of Agricultural Sciences, Bengaluru, Karnataka during January 2022 to July 2022. The experimental plot was established in July 2017 and consists of eight Pongamia germplasms, planted at 5X5 meters spacing. These eight Pongamia germplasms are aligned in a Randomized Complete Block Design (RCBD) with three replications. Cowpea was cultivated as an intercrop in the interspaces between the rows of Pongamia germplasms. Details of the eight Pongamia germplasms with intercrop cowpea are given in Table1..

**Table 1:** Details of the experimental site

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Germplasm** | **Germplasm collection** | **Intercrop** |
| **T1** | RAK-2015-01 | MPKV, Rahuri | Cowpea |
| **T2** | RAK-2015-02 | MPKV, Rahuri | Cowpea |
| **T3** | RAK-2015-03 | MPKV, Rahuri | Cowpea |
| **T4** | RAK-2015-04 | MPKV, Rahuri | Cowpea |
| **T5** | RAK-2015-07 | MPKV, Rahuri | Cowpea |
| **T6** | RAK-2015-08 | MPKV, Rahuri | Cowpea |
| **T7** | RAK-2015-09 | MPKV, Rahuri | Cowpea |
| **T8** | RAK-2015-10 | MPKV, Rahuri | Cowpea |

*Litter fall quantification:* Leaf litter was collected using the litter traps. 1 m × 1 m dimension shade nets were used as litter traps (Sundarapandian and Swamy, 1999). Under each tree, soil up to 10 cm depth was removed and 1 m × 1 m dimension litter traps were placed above them. Twenty-four litter traps were placed under the plantation of Pongamia. Litter was collected at monthly intervals. The collected litter was washed and oven dried at 70-80°C for 48 hours and weight was recorded. Average of the monthly data is considered as total litter fall.

*Nutrient analysis of litter:* The washed, oven dried litter samples were powdered. The powdered samples were sieved and stored in the airtight bag for the chemical analysis. One gram of the powdered sample was digested with triacid digestion mixture (9:4:1 part of HNO3, H2SO4 and HClO4). After the completion of the digestion, the volume was made up to 50 ml using distilled water. The methodologies adopted to estimate the following nutrients of the litter are given in Table 2.

.**Table 2:** Details of the methodology adopted for nutrient analysis in leaf and rachis.

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Methodology** | **Reference** |
| **Total nitrogen** | Di-acid extract - Kjeldahl distillation method | Jackson (2005) |
| **Total phosphorus** | Triple acid extract- colorimetric method | Jackson (2005) |
| **Total potassium** | Triple acid extract- flame photometric method | Jackson (2005) |

*Collection of soil samples for analysis of chemical properties*: The soil samples were collected from the agroforestry plot at 0-15 cm, 15-30 cm and 30-45 cm depth to estimate the soil organic carbon present at various depths. Whereas, soil samples were collected at 0-15 cm is to estimate pH, EC, N, P2O5 and K2O respectively. Totally 24 samples were collected for the estimation of pH, EC, N, P2O5 & K2O and 24 samples were collected for the estimation of organic carbon at different depths. Thus, a total of 48 samples were collected for soil analysis.

*Laboratory analysis of soil samples:* Soil samples were dried under shade and gently crushed in mortar and sieved using 2 mm sieve. They were analyzed for chemical properties such as pH, EC, N, P2O5, K2O and for organic carbon using standard procedures as given below (Table 3).

*Carbon sequestration in soil:* The carbon stock in soil is determined at the depth of 15, 30 and 45cm using the following formula.

**Carbon Stock (Mg C/ha) = BD (g/cc) x OC (%) x depth (m)**

Whereas, **BD** – Bulk density of the soil and **OC** – Organic carbon in soil

**Table 3:** The details of the methodology adopted for soil analysis

|  |  |  |
| --- | --- | --- |
| **Particulars** | **Methodology adopted** | **Reference** |
| **pH** | 1:2.5 soil water suspension with the help of digital pH meter | Jackson (1973) |
| **EC (dsm-1)** | 1:2.5 soil water suspension using conductivity bridge | Jackson (1973) |
| **Organic Carbon (per cent)** | Walkley and Black rapid titration method | Walkley and Blacky (1938) |
| **Available Nitrogen (kg ha-1)** | Alkaline potassium permanganate method | Subbiah and Asija (1956) |
| **Available Phosphorus (kg ha-1)** | Spectrophotometric (Bray’s Extraction method with 0.03 N NH4F + 0.025 N HCl) | Jackson (1973) |
| **Available Potassium (kg ha-1)** | Flame photometric (Extraction with N NH4OAc of pH 7) | Jackson (1973) |

*Statistical Analysis*: Experimental data obtained were subjected to statistical analysis adopting Fisher’s method of ‘analysis of variance’ as out lined by Gomez and Gomez (1984). Critical difference (CD) values are given in the table at 5 per cent level of significance for agroforestry studies, wherever the ‘F’ test was found significant.

**RESULTS AND DISCUSSION**

The monthly average and total annual leaf litter production in Pongamiafor the study period from January 2022 to June 2022 is presented in Table 4. It was noticed that leaf litterfall followed a unimodal pattern and a distinct peak was seen in February of 2022. The maximum accumulation of litterfall was recorded highest in the month of February in all the treatments and **RAK-2015-10** showed the higher accumulation of litterfall in the month of February (187.85 kg ha-1) and the lowest in the month of June (100.70 kg ha-1). The higher amount of total litter and mean accumulation of litterfall was accumulated in the month of February (1368.15 kg ha-1 &171.01 kg ha-1) and lower in the month of June (693.20 kg ha-1 & 86.65 kg ha-1) respectively. Studies have shown that litter (leaf and rachis) contribution varied with the tree growth, tree age, tree density, canopy characteristics (canopy spread and canopy shape) and seasons of leaf shed (Mohsin *et al.* (1996), Singh *et al.* (1998) and Bhardwaj *et al*. (2001)).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Germplasm** | **Litter fall (kg ha-1)** | | | | | | | |
| January | February | March | April | May | June | Total | **Mean** |
| RAK-2015-01 | 149.09 | 164.50 | 151.02 | 121.50 | 103.10 | 81.30 | 770.51 | 128.41 |
| RAK-2015-02 | 145.43 | 160.90 | 147.71 | 119.20 | 100.20 | 78.90 | 752.34 | 125.39 |
| RAK-2015-03 | 156.52 | 172.90 | 159.00 | 127.95 | 109.80 | 87.10 | 813.27 | 135.54 |
| RAK-2015-04 | 152.92 | 168.30 | 154.40 | 123.30 | 104.70 | 83.50 | 787.12 | 131.18 |
| RAK-2015-07 | 161.40 | 176.70 | 162.60 | 130.50 | 111.20 | 89.60 | 832.00 | 132.66 |
| RAK-2015-08 | 165.39 | 179.70 | 162.05 | 131.40 | 117.10 | 94.50 | 850.14 | 141.69 |
| RAK-2015-09 | 142.76 | 157.30 | 144.70 | 115.95 | 98.80 | 77.60 | 737.11 | 122.85 |
| RAK-2015-10 | 171.11 | 187.85 | 169.50 | 138.00 | 123.00 | 100.70 | 890.16 | 148.36 |
| **TOTAL** | 1244.62 | 1368.15 | 1250.93 | 1007.80 | 867.90 | 693.20 | **-** | **-** |
| **MEAN** | 155.57 | 171.01 | 156.36 | 125.97 | 108.48 | 86.65 | **-** | **-** |

**Table 4:** Total litterfall (kg ha-1) in Pongamia from January to June, 2022 as influenced by germplasms

The amount of major nutrients such as nitrogen, phosphorous and potassium content in leaf and rachis found to be non significant. However, higher nitrogen content in the leaf and rachis was observed in **RAK-2015-04** (1.13% & 1.11%). This was followed by **RAK-2015-03** (1.07% & 1.06%) and **RAK-2015-10** (0.94% & 0.93%) respectively. The lower nitrogen content in leaf and rachis was recorded in **RAK-2015-01** (0.42% & 0.42%). The higher phosphorous content in the leaf and rachis was observed in **RAK-2015-09** (0.128% & 0.121%). This was followed by **RAK-2015-04** (0.081% & 0.069%) and **RAK-2015-07** (0.074% & 0.062%) respectively. The lower phosphorous content in leaf and leaf was recorded in **RAK-2015-08** (0.033% & 0.030%). The higher potassium content in the leaf was observed in **RAK-2015-04** (1.097%). This was followed by **RAK-2015-03** (0.947%) and **RAK-2015-07** (0.867%). The lower potassium content in leaf was recorded in **RAK-2015-01** (0.363%). In case of rachis, the higher Potassium content was observed in **RAK-2015-03** (1.15 %). This was followed by **RAK-2015-04** (1.04 %) and **RAK-2015-02** (0.93 %). The lower Potassium content in rachis was recorded in **RAK-2015-01** (0.65 %) and **RAK-2015-08** (0.65 %) (Table 5 & 6). Similar results was observed by Usharani *et al.* (2019).

**Table 5:** Per cent N, P and K content in the fallen leaves of Pongamia during September, 2022 as influenced by germplasms

|  |  |  |  |
| --- | --- | --- | --- |
| **Germplasms** | **N (%)** | **P (%)** | **K (%)** |
| RAK-2015-01 | 0.42 | 0.055 | 0.363 |
| RAK-2015-02 | 0.84 | 0.054 | 0.743 |
| RAK-2015-03 | 1.07 | 0.043 | 0.947 |
| RAK-2015-04 | 1.13 | 0.081 | 1.097 |
| RAK-2015-07 | 0.72 | 0.074 | 0.867 |
| RAK-2015-08 | 0.71 | 0.033 | 0.633 |
| RAK-2015-09 | 0.87 | 0.128 | 0.727 |
| RAK-2015-10 | 0.94 | 0.056 | 0.797 |
| **F-test** | **NS** | **NS** | **NS** |
| **S.Em ±** | 0.04 | 0.017 | 0.064 |
| **CD (p=0.05)** | - | - | - |

\*Significant at 5% level of significance NS-non significant

**Table 6:** Per cent N, P and K content in the Rachis of Pongamia during September, 2022 as influenced by germplasms

|  |  |  |  |
| --- | --- | --- | --- |
| **Germplasms** | **N (%)** | **P (%)** | **K (%)** |
| RAK-2015-01 | 0.42 | 0.051 | 0.65 |
| RAK-2015-02 | 0.83 | 0.046 | 0.93 |
| RAK-2015-03 | 1.06 | 0.030 | 1.15 |
| RAK-2015-04 | 1.11 | 0.069 | 1.04 |
| RAK-2015-07 | 0.71 | 0.062 | 0.89 |
| RAK-2015-08 | 0.70 | 0.027 | 0.65 |
| RAK-2015-09 | 0.86 | 0.121 | 0.82 |
| RAK-2015-10 | 0.93 | 0.049 | 0.92 |
| **F-test** | **NS** | **NS** | **NS** |
| **S.Em ±** | 0.04 | 0.017 | 0.155 |
| **CD (p=0.05)** | - | - | - |

\*Significant at 5% level of significance NS- Non significant

The chemical parameters of soil *viz.* pH, electrical conductivity (dS m-1), available N (Kg ha-1), P (Kg ha-1), K (Kg ha-1) and OC (%) were presented in the Table 7& 8, i.e., before sowing and after the harvest of intercrop. The pH of the soil found acidic and it varies from 5.24 to 5.57 & 5.22 to 5.53 before the crop sown and after the harvest of the crop respectively. The highest pH values was recorded in **RAK-2015-10** (5.57 & 5.53) followed by **RAK-2015-08** (5.51 & 5.49) and **RAK-2015-07** (5.46 & 5.44). The lower pH value was observed in **RAK-2015-09** (5.24 & 5.22). The variation in soil pH was due to increase in production of organic acids and partial pressure of CO2, during organic matter decomposition. These results are in similar with those reported by Singh *et al.* (2014).

The EC of the soil varies from 0.35 dS m-1 to 0.48 dS m-1 & 0.32 dS m-1 to 0.46 dS m-1 before the crop sown and after the harvest of the crop respectively. The highest EC values was recorded in **RAK-2015-09** (0.48 dS m-1 & 0.46 dS m-1) followed by **RAK-2015-02** (0.47 dS m-1  & 0.44 dS m-1) and **RAK-2015-01** (0.46 dS m-1 & 0.41 dS m-1). The lower EC value was observed in **RAK-2015-10** (0.35 dS m-1 & 0.32 dS m-1). The variation in the EC may be due to extraction of salts from the higher depth to surface soil from the roots of the tree and it may also due to leaves felled from the trees. This was in accordance with Maria *et al.* (2013).

The organic carbon in soil at 0-15 cm depth varies from 0.42% to 0.54% & 0.40% to 0.52% before the crop sown and after the harvest of the crop respectively. The highest organic carbon value was recorded in **RAK-2015-10** (0.54% & 0.52%) followed by **RAK-2015-08** (0.52% & 0.50%) and **RAK-2015-07** (0.50% & 0.49%). The lower organic carbon values were observed in **RAK-2015-02** (0.42% & 0.40%). The organic carbon in soil at 15-30 cm depth before the crop sown and after the harvest of the crop varies from 0.23% to 0.36% & 0.20% to 0.34% respectively. The highest organic carbon content was recorded in **RAK-2015-10** (0.36% & 0.34%) followed by **RAK-2015-08** (0.33% & 0.32%) and **RAK-2015-07** (0.32% & 0.30%). The lower organic carbon value was observed in **RAK-2015-09** (0.23% & 0.20%). The organic carbon in soil at 30-45 cm depth before the crop sown and after the harvest of the crop varies from 0.17% to 0.27% & 0.14% to 0.25% respectively. The highest organic carbon values was recorded in **RAK-2015-10** (0.27% & 0.25%). This was followed by **RAK-2015-07** (0.22 %) and **RAK-2015-08** (0.22%) respectively. The lower organic carbon value was observed in **RAK-2015-02** (0.17 %) and **RAK-2015-09** (0.14%) respectively. It was observed with the increasing soil depth (from surface to 45cm depth), the organic carbon content decreased relatively. The above ground biomass incorporation is higher that the below ground biomass at all soil depths, so that soil organic content higher in surface soil. This was in accordance with Sheikh *et al*. (2009).

Among eight Pongamia germplasms, significantly higher available nitrogen was observed in **RAK-2015-10** (278.18 kg ha-1 & 265.52 kg ha-1) before the crop sown and after the harvest of the crop respectively. This was followed by **RAK-2015-08** (274.26 kg ha-1 & 262.94 kg ha-1) and **RAK-2015-07** (254.28 kg ha-1 & 246.64 kg ha-1). The lowest available nitrogen was found in **RAK-2015-09** (235.28 kg ha-1 & 224.39 kg ha-1). Due to the higher accumulation of litter fall in **RAK-2015-10** on top soil have contributed to the higher organic matter and this organic matter is good source of soil available nitrogen. Similar results were observed by Eghball *et al.* (1994).

The available phosphorous content of the soil before the crop sown and after the harvest of the crop varies from 22.25 kg ha-1 to 29.65 kg ha-1 & 17.97 kg ha-1 to 22.86 kg ha-1 respectively. The highest available phosphorous values was recorded in **RAK-2015-10** (29.65 kg ha-1 & 22.86 kg ha-1) followed by **RAK-2015-08** (25.69 kg ha-1 & 20.73 kg ha-1) and **RAK-2015-07** (25.39 kg ha-1 & 20.11 kg ha-1). The lower available phosphorous value was observed in **RAK-2015-09** (22.25 kg ha-1 & 17.97 kg ha-1). The increased concentration of phosphorous content in RAK-2015-10 might be due to presence of higher phosphorous content in the leaves of the respective germplasms. The decrease in the phosphorous concentration after the harvest of the crop might be due to the uptake of phosphorous by the plants. This was similar to the results obtained from Jackson *et al*. (1973).

The available potassium content of the soil before the crop sown and after the harvest of the crop varies from 190.26 kg ha-1 to 211.09 kg ha-1 & 180.18 kg ha-1 to 203.19 kg ha-1 respectively. The highest available potassium content values was recorded in **RAK-2015-10** (211.09 kg ha-1 & 203.19 kg ha-1) followed by **RAK-2015-08** (208.19 kg ha-1 & 199.07 kg ha-1) and **RAK-2015-07** (207.25 kg ha-1 & 196.73 kg ha-1). The lower available potassium value was observed in **RAK-2015-09** (190.26 kg ha-1 &180.18 kg ha-1). Trees with their deep roots absorb soil nutrients from deeper layer of soil and with the litterfall these nutrients are again added to the top layer of soil. Thus, the available nutrients released from the litter decomposition will be utilized by the intercrops, so it will possibly result in the reduction of nutrients in the soil after the harvest of intercrops. This was similar to the results obtained from De Costa and Chandrapala (2000).

**Table 7:** Chemical properties of soil soil before the crown grown as influenced by Pongamia based agroforestry system

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Germplasms** | **pH (1:2.5)** | **EC**  **(dsm-1)** | **Organic carbon (%)** | | | **Avail. N (kg ha-1)** | **Avail. P2O5**  **(kg ha-1)** | **Avail. K2O**  **(kg ha-1)** |
| **0- 15**  **cm** | **15-30**  **cm** | **30-45**  **cm** |
| RAK-015-01 | 5.28 | 0.41 | 0.43 | 0.26 | 0.17 | 232.94 | 18.46 | 182.88 |
| RAK-015-02 | 5.24 | 0.44 | 0.40 | 0.22 | 0.16 | 225.88 | 18.21 | 180.68 |
| RAK-015-03 | 5.37 | 0.36 | 0.47 | 0.29 | 0.20 | 245.25 | 19.53 | 190.67 |
| RAK-015-04 | 5.31 | 0.37 | 0.44 | 0.26 | 0.17 | 234.53 | 18.79 | 183.94 |
| RAK-015-07 | 5.44 | 0.34 | 0.49 | 0.30 | 0.21 | 246.64 | 20.11 | 196.73 |
| RAK-015-08 | 5.49 | 0.33 | 0.50 | 0.32 | 0.22 | 262.94 | 20.73 | 199.07 |
| RAK-015-09 | 5.22 | 0.46 | 0.40 | 0.20 | 0.14 | 224.39 | 17.97 | 180.18 |
| RAK-015-10 | 5.53 | 0.32 | 0.52 | 0.34 | 0.25 | 265.52 | 22.86 | 203.19 |
| **F- test** | **NS** | **NS** | **NS** | **NS** | **NS** | **\*** | **NS** | **NS** |
| **S.Em ±** | **0.49** | **0.03** | **0.04** | **0.06** | **0.02** | **0.46** | **1.78** | **52.12** |
| **C. D @ 5%** | **-** | **-** | **-** | **-** | **-** | **1.40** | **-** | **-** |

\*Significant at 5% level of significance NS- Non significant

**Table 8:** Chemical properties of as influenced by Pongamia based agroforestry after the harvest of intercrop

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Germplasms** | **pH (1:2.5)** | **EC**  **(dsm-1)** | **Organic carbon (%)** | | | **Avail. N (kg ha-1)** | **Avail. P2O5**  **(kg ha-1)** | **Avail. K2O**  **(kg ha-1)** |
| **0- 15**  **cm** | **15-30**  **cm** | **30-45**  **cm** |
| RAK-015-01 | 5.32 | 0.46 | 0.46 | 0.28 | 0.18 | 242.56 | 23.58 | 191.52 |
| RAK-015-02 | 5.26 | 0.47 | 0.42 | 0.24 | 0.17 | 232.47 | 23.72 | 190.46 |
| RAK-015-03 | 5.39 | 0.38 | 0.48 | 0.31 | 0.22 | 253.14 | 24.41 | 200.76 |
| RAK-015-04 | 5.27 | 0.39 | 0.45 | 0.27 | 0.20 | 242.28 | 23.48 | 191.78 |
| RAK-015-07 | 5.46 | 0.36 | 0.50 | 0.32 | 0.22 | 254.28 | 25.39 | 207.25 |
| RAK-015-08 | 5.51 | 0.36 | 0.52 | 0.33 | 0.21 | 274.26 | 25.69 | 208.19 |
| RAK-015-09 | 5.24 | 0.48 | 0.45 | 0.23 | 0.18 | 235.28 | 22.25 | 190.26 |
| RAK-015-10 | 5.57 | 0.35 | 0.54 | 0.36 | 0.27 | 278.18 | 29.65 | 211.09 |
| **F- test** | **NS** | **NS** | **NS** | **NS** | **NS** | **\*** | **NS** | **NS** |
| **S.Em ±** | **0.04** | **0.03** | **0.01** | **0.01** | **0.01** | **0.93** | **0.50** | **2.99** |
| **C. D @ 5%** | **-** | **-** | **-** | **-** | **-** | **3.13** | **-** | **-** |

\*Significant at 5% level of significance NS- Non significant

The carbon sequestration in the soil at different depths (0-15 cm, 15-30 cm and 30-45 cm) varies significantly, as it was influenced by Pongamiagermplasms (Table 9). The highest carbon stock in the soil was present in the top soil (0-15 cm) when compared to the different depths like 15-30 cm and 30-45 cm. The total carbon stock in the soil was present highest in **RAK-2015-10** (22644 kg ha-1) among different germplasms. This was followed by **RAK-2015-08** (21216 kg ha-1) and **RAK-2015-07** (20400 kg ha-1). The lowest carbon stock in the soil was observed in **RAK-2015-09** (15096 kg ha-1). The higher accumulation in the top soil might be due higher accumulation organic carbon by the decomposition of leaf litter by the Pongamia germplasms. Similar variations in soil carbon stock with increasing depth have been reported by earlier studies of Singh and Sharma, (2012); Swamy and Puri, (2005) and Chauhan *et al.* (2010).

**Table 9: Carbon sequestration in soil (kg ha-1) as influenced by different Pongamia germplasms.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Germplasm** | **0-15 cm** | **15-30 cm** | **30-35 cm** | **Total** |
| RAK-2015-01 | 8772 | 5304 | 3468 | 17544 |
| RAK-2015-02 | 8160 | 4488 | 3264 | 15912 |
| RAK-2015-03 | 9588 | 5916 | 4080 | 19584 |
| RAK-2015-04 | 8976 | 5304 | 3468 | 17748 |
| RAK-2015-07 | 9996 | 6120 | 4284 | 20400 |
| RAK-2015-08 | 10200 | 6528 | 4488 | 21216 |
| RAK-2015-09 | 8160 | 4080 | 2856 | 15096 |
| RAK-2015-10 | 10608 | 6936 | 5100 | 22644 |
| **S.Em ±** | **10** | **11** | **8** | **-** |
| **C. D @ 5%** | **33** | **34** | **26** | **-** |

**CONCLUSION**

The present study on nutrient and litter dynamics in a cowpea + Pongamia agroforestry system highlights the ecological and agronomic advantages of integrating leguminous cover crops with perennial tree species. Among the eight pongamia germplasms, interaction between RAK-2015-10 and cowpea shown that highest synergistic through improved nitrogen fixation and organic matter input but also contributes to sustainable nutrient cycling via increased litter production and decomposition. The results indicate that the integrated system of RAK-2015-10 and cowpea have the potential to improve nutrient availability, reduce dependence on external inputs and promote long-term soil health. These findings underscore the value of agroforestry as a viable land-use strategy for sustainable agriculture in semi-arid and resource-constrained regions. Further long-term studies are recommended to understand seasonal variations and the cumulative impacts of litter dynamics on ecosystem productivity.

**REFERENCES**

BHARDWAJ, S. D., PANWAR, P. AND GAUTAM, S., 2001, Biomass production potential and nutrient dynamics of *Populus deltoides* under high density plantations. *Indian forester*, **127**(2): 144-153.

CHAUHAN, S. K., SHARMA, S. C., BERI, V., RITU, YADAV, S. AND GUPTA, N., 2010, Yield and carbon sequestration potential of wheat (*Triticum aestivum*)-poplar (*Populus deltoides*) based agri-silvicultural system. *Indian J. Agri. Sci*., (2): 129-135.

DE COSTA, W. A. J. M. AND CHANDRAPALA, A. G., 2000, Environmental interactions between different tree species and mung bean (*Vigna radiata* (L.) Wilczek) in hedgerow intercropping systems in Sri Lanka. *J. Agron. Crop Sci*., **184**(3): 145-152.

EGHBALL, B., LLOYD, N. M., DENNIS, L. M. AND JOHN, W. D., 1994, Distribution of organic carbon and inorganic nitrogen in a soil under various tillage and crop sequence. *Soil and water conserve*., **49**:201-205.

GILLER, K. E. (2001). *Nitrogen Fixation in Tropical Cropping Systems*. CABI.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedures for agricultural research, an international Rice Research Institute book, Wiley-Inter science Publication, John Wiley and Sons, New York.

JACKSON, M. L., 2005, *Soil chemical analysis: Advanced course.* UW-Madison Libraries Parallel Press.

JACKSON, M. L., 1973, Soil chemical analysis: Advanced course. UW-Madison Libraries Parallel Press.

JACKSON, M. L., 1973, *Soil Chemical Analysis*. Prentice Hall of India, New Delhi.

JOSE, S., (2009). Agroforestry for ecosystem services and environmental benefits. *Agroforestry Systems*, 76, 1–10.

MARIA, J. A., BERTALOT, A., IRAE, A., GUERRINI, B., EDUARDO, M. A., MAURO, S. V. AND PINTO, S. V., 2013, Influence of agroforestry and traditional management of maize (*Zea mays* L.) on soil fertility. *J. Sustain. For*., **32**: 495-511.

MOHSIN, F., SINGH, R. P. AND SINGH, K., 1996, Nutrient cycling of poplar plantation in relation to stand age in agroforestry system. *Indian J. Forester*., **19**(4): 302-310.

NAIR, P. K. R., (2011). Agroforestry and soil quality. *Journal of Environmental Quality*, 40(3), 784–790.

PALM, C.A., GACHENGO, C.N., DELVE, R.J., CADISCH, G. AND GILLER, K.E., (2001). Organic inputs for soil fertility in tropical agroecosystems. *Agriculture, Ecosystems & Environment*, 83(1-2), 27–42.

SCOTT, P. T., PREGELJ, L., AND CHEN, N., (2008). *Pongamia pinnata*: An untapped resource for the biofuels industry. *BioEnergy Research*, 1(1), 2–11.

SHEIKH, M. A., KUMAR, M. AND BUSSMAN, R. W., 2009, Altitudinal variation in soil organic carbon stock in coniferous subtropical and broadleaf temperate forests in Garhwal Himalaya. *Carbon balance management*, **4**: 1-16.

SINGH AND SHARMA., 2012, *Sesbenia grandiflora*: Forage yield and nutritive value of intensive silvopasture systems. *Agrofor. Syst*., **43** (4): 84-102.

SINGH, B., BISHNOI, M., BALOCH, M. R. AND SINGH, G., 2014, Tree biomass, resource use and crop productivity in agri-horti-silvicultural systems in the dry region of Rajasthan, India. *Arch. Agron. Soil Sci.*, **60**(8): 1031-1049.

SINGH, B.B., CHAMBLISS, O.L. AND SHARMA, B., (1997). Recent advances in cowpea breeding. International Institute of Tropical Agriculture (IITA), 30–49.

SINGH, G., N.T. SINGH, J.C. DAGAR, H. SINGH AND V.P. SHARMA, 1998, An evaluation of agriculture, forestry and agroforestry practices in a moderately alkali soil in north western India. Agroforestry systems, **37**(3): 279-295.

SUBBIAH, B. V. AND ASIJA, G. L., 1956, A rapid procedure for estimation of available N in soil, *Curr. Sci.,* **25**: 259-260.

SUNDARAPANDIAN, S. M. AND SWAMY, P. S., 1999, Litter production and leaf- litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India. *For. Ecol. Manag.*, **123**(3): 231-244.

SWAMY, S. L. AND PURI, S., 2005, Biomass production and C-sequestration of *Gmelina arborea* in plantation and agroforestry system in India. *Agrofor. Syst.*, **64**(3): 181- 195.

USHARANI, K. V., ROOPASHREE, K. M. AND NAIK, D. (2019). Role of soil physical, chemical and biological properties for soil health improvement and sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry*, 8(5), 1256-1267.

WALKLEY, A. AND BLACK, I. A., 1938, An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.,* **37**: 29-37.