Print : ISSN 0970-7662

Journal of Tree Sciences
online available at www.ists.in

Volume 32 No.1&2 June & December, 2013

Leaf Litter Fall and Decomposition of Poplar (*Populus deltoides*) under Intensively Managed Wheat Based Agroforestry System

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ABSTRACT

Leaf litter decomposition is a fundamental process of ecosystem functioning which is closely linked to the nutrient recycling for plant growth. Leaf litter fall and decomposition pattern was studied in 3 and 4 years old poplar (Populus deltoides) planted as boundary plantation in wheat based intensively managed agroforestry system. Litter bags were randomly placed within 3m, 3 to 6m, 6 to 9m and beyond 15 m distance from tree base line. Litter bags were removed after 30 days (at crown root initiation stage of wheat), 90 days (at reproductive stage of wheat), 140 days (at maturity of wheat), and after one year of placement (before sowing of next wheat crop) respectively for determining decomposition rate of leaf litter. Litter fall was restricted up to a distance of 9 m from the tree line and total amount of 913.8 and 1291.8 kg ha^{-1} was recorded with 3 and 4 years old plantation. Fifty seven per cent of total leaf fall was recorded near the tree line (0-3m) with 3 years old plantation which came down to 46 per cent with advancement of plantation age to 4 years. Loss in weight revealed that 19.3 to 18.4 per cent loss in dry mass of leaf litter was observed in control during first 30 days after placement, whereas, loss in mass varied between 18.8 to 23.5 per cent under the tree influence area during same period in both the years. It was found that irrespective of distances 47 to 52.9 per cent mass of leaf litter was lost up to harvesting of wheat. Maximum mass loss was recorded near tree line (0-3 m distance) before harvesting of wheat. Overall, the highest values (1.823 and 1.754) of decomposition constant (k) were obtained in control in both 3 and 4 years old plantation, respectively.

Keywords:

Agroforestry, decomposition, litter, poplar, wheat

INTRODUCTION

A considerable amount of leaf shed by poplar trees during winter eventually reach the soil where they decompose and change the nutrient status of the soil. During initial stages of decomposition, the nutrient status of soil may be affected through immobilization and later on through mineralization. Leaf spread during leaf fall can extend beyond the crown diameter of trees. Thus, the decomposition of leaf litter will take place at different rates which may vary with respect to the site. Decomposition is a function of temperature, moisture and leaf litter quality which can be modified in presence of tree canopy and intensity of management. A change in rate of decomposition can be expected with boundary plantation of poplar in an intensively managed wheat based agroforestry system. Therefore, an experiment was conducted using litter bag technique to find out the rate of decomposition of poplar leaf litter at different distances from tree line in the intensively managed wheat based agroforestry system.

MATERIALS AND METHODS

The study was carried out at the Research farm of J.V. College, Baraut at an altitude of230 m above mean sea level between 29° 6'N latitude and 77° 60'E longitude. The soil of the study area was sandy clay loam with loam beneath 45 cm depth. pH ranging from 6.5-7.1 and organic carbon and total nitrogen, available phosphorus, available potassium ranged between 0.10-0.54 %, 0.03 and 0.08 % , 15.3 and 26.3 kg ha^{-1}, and 105 and 130 kg ha^{-1} respectively in soil profile of 0-90 cm depth. Bulk density, field capacity, permanent wilting points and water holding capacity ranged from 1.47 to 1.44 g cm^{-3}, 17.9 to 21.3 %, 7.3 to 13.1 % and 42.2 to 46.5 % respectively.

The experiment was conducted in an agriculture field having a single row boundary plantation of three years old *Populus deltoides* (clone G-3) spaced at 3.5 m. Litterfall was measured by randomly laying litter trap of 1x1 m size within 3m, 3 to 6m, 6 to 9m and beyond 15 m distance from tree base line. Litter bags technique was employed to study the decomposition rate of leaf litter. (Shanks and Olson 1961; Pande and Sharma 1993; Raizada 1988). Nearly senescent leaves (nearly yellow) were collected from the middle canopy of three and four years old poplar plantation. Composite samples were made by mixing the leaves. 25 g of air dried leaves were placed in nylon litter bags of 45 x 25 cm in size having a mesh size of 2 mm. Bags were stapled all along the sides at 5 cm intervals leaving enough gap between two staples to ease the entry of most of the macro fauna. Four such samples of leaves were also taken for recording their oven-dry weight to serve as the initial samples standard (i.e. 0% leaf decay). In all, 64 litter bags were prepared and placed in the field. Bags were randomly placed within 3m, 3 to 6m, 6 to 9m and beyond 15 m distance from tree base line (independent from tree effect). Only three points were selected between 0-15m distance because the leaf fall was observed up to 9m towards the centre of field. Fourth point was considered as control because this area was not influenced by the tree line. Sixteen bags were placed randomly in a plot measuring 5 3 m in such a way that their lower surface was in firm contact with the soil and upper surface was covered with 1 cm layer of soil. The bags were placed on 5 December which coincides with the time of maximum leaf fall.

Four bags from each set were recovered randomly at after 30 days (at crown root initiation stage of wheat), 90 days (at reproductive stage of wheat), 140 days (at maturity of wheat), and after one year of placement (before sowing of next wheat crop) respectively. The residual litter was brought to the laboratory then, washed under running water, over a sieve of mesh size 0.5 0.5 mm to remove the soil particles, and then oven dried at 60°C to constant weight. Weight loss calculated based on the initial weight (zero per cent decay).

Weight loss of decomposing biomass was described by the single exponential decay function as (Olson 1963):

$$W_t/W_0 = e^{-kt}$$

Where W_o and W_t are litter dry weights at the beginning and after time t (in days) respectively. The decomposition constant (k) was estimated as the slope of the linear regression between $\log_e (W_t/W_0)$ and t.

RESULTS AND DISCUSSION

After harvesting of *kharif* crop (October), there was a continuous fall of poplar leaves which extended up to first fortnight of January. Litter fall was restricted up to a distance of 9m from the tree line and total amount of 913.8 and 1291.8 kg ha^{-1} was recorded with 3 and 4 years old plantation (Table 1). Maximum amount of leaf fall was collected from 0-3m distance and reduced with increase in distance from tree line. Percentage of leaf fall was reduced near the tree line (0-3m) as a function of age/height of trees. Fifty seven per cent

Table 1: Litter fall (kg ha^{-1}) of poplar tree line at different distances from tree line, during the winter season (October-April)

Distance from tree line (m)	Litter fall (kg ha^{-1})		
	3-yr old	4-yr old	Mean
0-3	520.9	593.9	557.4
	(57.0)	(46.0)	(50.5)
3-6	283.3	451.9	367.6
	(31.0)	(35.0)	(33.3)
6-9	109.7	245.3	177.5
	(12.0)	(19.0)	(16.1)
Total	913.8	1291.8	1102.8

* Figure in parenthesis are percentages of total leaf biomass

Table 2: Dry weight (g) of poplar leaf litter at different time and distances from tree line

Distance from tree line (m)	3-yr old					4-yr old				
	Days after placement									
	30	90	140	One year	Mean	30	90	140	One year	Mean
0-3	17.9	13.1	11.0	7.1	12.3	18.1	13.1	11.3	6.7	12.3
3-6	17.2	13.7	11.7	6.1	12.2	17.2	13.4	11.6	6.0	12.0
6-9	17.3	14.0	11.1	4.1	11.6	17.1	13.7	10.9	4.3	11.5
Control*	18.0	14.8	10.5	3.6	11.7	18.2	14.9	10.5	3.9	11.8
Mean	17.6	13.9	11.1	5.2		17.6	13.8	11.1	5.2	
LSD(P = 0.05)										
Time			0.8					0.9		
Distance			N.S.					NS		
Interaction (Time x Distance)			1.7					1.7		

*Recorded 15m away from tree line; N.S. = Non significant

Table 3: Per cent reduction of original leaf litter mass

Distance (m) from tree line	3-yr old				4-yr old			
	Days after placement							
	30	90	140 (at wheat harvest)	After one year	30	90	140 (at wheat harvest)	After one year
0-3	19.7	41.3	50.7	68.2	18.8	41.3	49.3	70.0
3-6	22.9	38.6	47.5	72.6	22.9	39.9	48.0	73.1
6-9	22.4	37.2	50.2	81.6	23.3	38.6	51.1	80.7
Control	19.3	34.5	52.9	83.9	18.4	33.2	52.9	82.5

Table 4: Decomposition constant (k), time to 50, 95 and 99 per cent decay for leaf litter at different distances from poplar tree line

Distance from tree line (m)	Decomposition Constant (k)			Time per cent decay								
				50			95			99		
	3-yr old	4-yr old	Mean	3-yr old	4-yr old	Mean	3-yr old	4-yr old	Mean	3-yr old	4-yr old	Mean
0-3	1.144	1.207	1.180	0.61	0.57	0.59	2.6	2.5	2.6	4.0	3.8	3.9
3-6	1.295	1.30	1.300	0.54	0.53	0.54	2.3	2.3	2.3	3.6	3.5	3.5
6-9	1.693	1.646	1.600	0.41	0.42	0.42	1.8	1.8	1.8	2.7	2.8	2.8
Mean*	1.377	1.388	1.383	0.52	0.51	0.52	2.2	2.2	2.2	3.4	3.4	3.4
Control**	1.823	1.754	1.789	0.38	0.40	0.39	1.7	1.7	1.7	2.5	2.6	2.6

* Mean between 0-9m distance; **Recorded 15m away from tree line

of total leaf fall was recorded near the tree line (0-3m) with 3 years old plantation which came down to 46 per cent with advancement of plantation age to 4 years. On an average, 557.4, 367.6 and 177.5 kg ha^{-1} leaf litter was collected between 0-3, 3-6 and 6-9m distance, respectively. It was estimated that, on an average, 44 and 56 per cent of total leaf fall took place before and after wheat sowing, respectively.

Data related to initial dry weight loss of leaf litter is given in Table 2. Mass remaining in the litter bags was not significantly different at any distance from tree line, however, at all the growth stages was significantly different in both the years. Data reveals that irrespective of distance, 17.6 and 17.6, 13. 9 and 13.8, 11.1 and 11.1, and 5.2 and 5.2g weight remained out of 22.3g (initial dry weight) at 30, 90, 140 (at wheat harvest) days and one year after placement, respectively. Interaction between distance and time was significant.

The data from Table 3 further revealed that 19.3 to 18.4 per cent loss in dry mass of leaf litter was observed in control during first 30 days after placement, whereas, loss in mass varied between 18.8 to 23.5 per cent under the tree influence area during same period in both the years. Highest (41.4 and 41.2%) reduction was observed between 0-3 m distance from tree line, in 3 and 4 years plantation respectively. No significant differences were observed upto wheat harvesting in both the years. However, significant difference was observed between distance and time during last stage (between harvesting of previous wheat crop, 140 days, and sowing of next wheat crop, after one year), which indicated that mass loss of initial was reduced significantly over control between 0-6 m distance from tree line in both the years, however, remained at par with control between 6-9 m distance. It was found that irrespective of distances 47 to 52.9 per cent mass of leaf litter was lost up to harvesting of wheat. Maximum mass loss was recorded near tree line (0-3 m distance) before harvesting of wheat. However, reverse trend was observed after wheat harvesting. Temperature and moisture is a prime factor in determining the rates of mass loss during the process of decomposition (Persons et al. 1990; Taylor and Parkinson 1988; Kaushal et al. 2005). Higher soil temperature was recorded near the tree line because large area of soil surface was exposed to sun radiation, caused by less plant population, small leaf area index during initial growth stages and less weed density as compared to control plot which was densely covered by the vegetation. However, soil temperature was reduced (4 °C) near the tree line during the month of April. This was due to the fact that shade is caused by the poplar crown as new leaves emerge after completion of dormancy period that was continued until next leaf fall. This may be the possible reason for slow rate of decomposition after wheat harvesting near the tree line (0-6 m distance). In the first stage of decomposition (up to 30 days after placement) maximum loss in leaf litter was recorded between 3-9 m distance. This may be due to high soil moisture at the surface soil (0-15 cm), as mass loss during initial stages is due to removal of leachable material (Parsons et al. 1990; Raizada 1988) which is a function of soil moisture status (Hill et al. 1992). No significant differences were observed due to distances during the initial stages of decomposition; however, after one year significantly less weight of leaf litter was lost under trees as compared to control (no tree). On an average, 69 to 83 per cent mass was lost from litter bags after one year which is comparable to that of intensively managed agroforestry system (Lekha et al. 1989). They reported that 63 to 94 per cent mass of leaf litter of poplar in litter bags was lost after 285 days in the intensively managed and irrigated poplar/leucaena-wheat based agroforestry system. However, Raizada (1988) found that leaves of poplar lost approximately 64 per cent of their original weight in one year under rainfed condition. Significant differences in leaf litter decomposition under trees as compared to control (no tree) can be attributed to variation in the rate of decomposition of litter which was caused by tree shade (Sae-Lee 1990), prevailed from March to December, and alteration of microclimate and environment (Klemmedson and Blaser 1988; Kaushal et al. 2006; Kaushal et al. 2012). Similarly, Ilangovan and Paliwal (1996) concluded that variations in leaf litter disappearance is related to environmental and soil variable. Their analysis indicated that relative humidity for environmental variable and soil temperature for soil variables were strongly correlated with leaf litter decomposition. Changes in soil temperature and microclimate due to shade may be the main reasons for variation in rate of decomposition of leaf litter.

The value of decomposition constant (k) and time for 50, 95 and 99 per cent decay was calculated and is given in Table 4. Considerable variation was recorded in k value due to the presence of trees as compared to control (no tree). As the value of time for different percentage of decay was calculated from k value, therefore, the trend obtained was same that of k value. The highest k values (1.823 and 1.754 in 3 and 4 years old plantation respectively) were obtained in control. Existence of trees caused reduction in k values in both the years and the estimated time of 50, 95 and 99 per cent decay increased by 36.8 to 27.5 per cent, 28.6 to 32.1 per cent and 36 to 28.5 per cent over control (no tree), respectively. Estimations revealed that irrespective of years and distance, on an average, 32.2 per cent more time was taken for 99 per cent decay of leaf litter in the field influenced by boundary plantation of poplar trees. Decomposition constant (k) values for leaf litter of poplar, estimated in the present study (intensively managed, fertilized and irrigated system) was higher than the estimation made in poplar plantation by Raizada 1988 and Singh et al. 1993.

They calculated 1.05 as a k value for poplar tree leaf litter under poplar block plantation. Differences in biotic and abiotic components of the systems are the major factors responsible for different k values in both the systems. Findings of Smith et al. (1993) helped to ascribed the differences in k values obtained in present and other studies. They concluded that soil moisture and fertility are most significant variables which influence the rate of decomposition. Similarly, Boerner (1984) reported that mass loss from litter bags was significantly higher in more fertile soil. He further suggested that litter fall, nutrient transfers and decomposition rate were under the control of soil nutrient level. Adedeji (1986) reported that addition of urea and NPK mixture to air dried litter increased decomposition rate.

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