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Effect of nitrogen fertilization on decomposition and nutrient release from poplar litter in Punjab state of India

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Abstract
A litter decomposition study using litterbags was conducted to assess influence of nitrogen levels (N_1: 120 kg N/ha and N_2: 180 kg N/ha) on decomposition, nutrient content and release from poplar litter aged two (2 Y) and five years (5 Y) during January to October in 2017. Litter quantity in litterbags was greater with N_1 under both 2 and 5 Y old poplar plantations. Highest increase in nitrogen content, while decrease in phosphorus and potassium content was observed during February to May. Release of N was maximum during May-August, while release of P and K was maximum during February-April with N_2 under both 2 and 5 Y old poplar plantations. However, the release of nutrients was higher in the plantation aged two years than the five years. The nutrient release pattern followed the order K>P>N.

Keywords: Litter decomposition, Nitrogen levels, Nutrient release, Poplar plantation

Introduction

Litterfall is a natural physiological phenomenon in trees having enormous implications in nutrient recycling, soil reclamation and yield of understory crops in agroforestry systems. It is a major pathway of nutrient input from trees to the forest floor through litter decomposition (Sugimoto *et al*., 2013). Poplar (*Populus deltoides* Bartr.) has been adopted by farmers of Punjab due to its short rotation and better economic returns than many other prevalent cropping systems in the region (Khullar *et al*., 2010). It is a winter deciduous tree and sheds most of its leaves during November and December leading to enrichment of soil with nutrients (Singh *et al*., 2007; Sunda *et al*., 2018). Magnitude of soil enrichment through litterfall depends upon the quantity and quality of litter added. Litter decomposition and nutrient release is a critical step linking ecosystem processes with plant productivity (Koukoura *et al.,* 2003).

Decomposition of litter is a sequential process whereby complicated organic compounds are broken into simpler substances thus releasing nutrients as by-products (Edmonds and Tuttle, 2010). Rate of litter decomposition is controlled by a number of biotic and abiotic factors like chemical composition of litter, environmental conditions (moisture availability, temperature), soil properties, decomposer communities, nitrogen concentration of litter and fertilizer application (Singh and Sharma, 2007; Vanderbilt *et al.,* 2008). Among all these factors, the soil fertilizer application altering the nutrient availability has been suggested as one of the important controlling factors affecting the rate of litter decomposition. Increased N fertilization enhanced the litter decomposition, N content and nutrient release from litter (Li *et al.,* 2011). During initial stage of litter decomposition, N can be a good predictor of decomposition rate; whereas in later stages, the chemical compounds in litter such as lignin can play a more important role. Therefore, understanding the litter decomposition and nutrient release pattern of litterfall helps in managing the litter inputs.

Little information is available regarding the effect of N fertilizers applied to intercrops in poplar plantations on decomposition of litter. Therefore, a litter decomposition study was conducted under field conditions for understanding the effects of nitrogen fertilization on litter decomposition rate, remaining amount of nutrients in the litter, nutrient content and their release in poplar plantations aged two and five years. The aims of the study were to determine the decomposition pattern of leaf litter with two nitrogen levels (120 and 180 kg N/ha) during different months of decomposition under two and five-year old poplar plantations and to evaluate the content and release of nutrients in litter.

Materials and Methods

***Experimental site*:** The experiment was conducted during 2017 in poplar plantations aged two years (2 Y) and five years (5 Y) at Research Farm of the Department of Forestry and Natural Resources, Punjab Agricultural University (PAU), Ludhiana, India. It is located at 30° 54´ N latitude and 78° 48´ E longitude at an elevation of 247 m above mean sea level. The climate of the experimental area is semi-arid. The mean monthly maximum temperature during 2017 ranged from 18.2°C (January) to 38.8°C (May) and mean minimum temperature ranged from 7.5°C (December) to 27.5°C (July). The total rainfall received during the year was 564 mm, which was lower than the previous year. Surface soil of the experimental site was sandy loam having $pH_{1:2}$ 8.1, electrical conductivity 0.28 dS/m, organic carbon 0.32%, available N-121.8 kg/ha, available P-9.2 kg/ha and available K-178.1 kg/ha.

***Experimental techniques and litter sampling*:** Leaf litter decomposition and nutrient release studies were initiated in poplar plantations aged 2 Y and 5 Y with two levels of nitrogen fertilizer [120 kg N/ha (N_1)- recommended dose of N for wheat and 180 kg N/ha (N_2)– 50% additional dose]. Litterbag technique was employed for leaf litter decomposition study (Wieder and Lang, 1982). One hundred twenty mesh bags of size 30×30 cm with mesh size 2 mm were filled with 30 g air dried leaf litter bag^{-1}. Bags were placed in plough layer of soil on 15 January with 2 cm thick soil layer spread over the bags. Three litterbags from each treatment were retrieved at monthly intervals from January to October till nearly 95% of decomposition was completed. The soil particles and foreign materials adhered with litter were removed, it was dried, weighed and powdered with Willey mill for chemical analysis. Litter remaining in the bags, nutrient content in the residual litter and its release was estimated.

***Nutrient analysis in the litter*:** The ground leaf litter samples were analysed for nitrogen (N), phosphorus (P) and potassium (K) contents. Nitrogen was analysed after digesting the samples with concentrated H_2SO_4 while other nutrients were estimated by digesting samples with diacid mixture (HNO_3:$HClO_4$ in 3:1). Total nitrogen content of leaf litter was determined using Kjeldahl¼s distillation method (Jackson, 1973). Total phosphorus content was determined by vanado-molybdo-phosphoric yellow colour method in nitric acid and potassium content by flame photometer method (Jackson, 1973). The remaining absolute amount of nutrients was calculated by multiplying nutrient content with quantity of litter remaining in bag. The release of nutrients (%) was estimated by dividing the fractional nutrient loss from the bags with input values of remaining absolute amount of nutrients.

***Statistical analysis*:** All the data sets were analysed with analysis of variance (ANOVA) calculated using CPCS1 statistical software of PAU Ludhiana. Analysis was conducted in randomized block design (RBD) taking nitrogen levels and decomposition months as two factors. The data so obtained were compared for significance of the difference by critical difference (CD) test at 5% level of significance.

Results and Discussion

Quantity of litter remaining in litterbags

The quantity of litter remaining in litterbags during different stages of decomposition with 2 nitrogen levels under 2 and 5 Y old poplar plantations was recorded (Table 1). Fertilization with increased N level (180 kg N/ ha) led to significant decrease in quantity of litter remaining in bags. On an average, the decrease in quantity of litter remaining in the bags with increased N fertilization from N_1 to N_2 was 11.1% in 2 Y and 9.75% in 5 Y old poplar plantations. The decline in amount of litter left over in the bags indicated the higher rate of litter decomposition on application of N_2 over N_1. Intensity of litter decomposition also varied significantly among different stages of its decomposition in both the plantations. The highest pulse of litter decomposition was observed during April to July i.e. the time period coinciding with highest temperature and moisture in the environment. Decomposition rate of litter was intermediate (17.7%) during initial two months (February and March) with further increasing to reach at its peak rate (44.6%) during April to July and lowest (8.2 %) during August to October under 2 Y old poplar plantation. On the other hand, decomposition rate was 14.1% during initial two months followed by its highest rate (40.4%) during April to July and lowest (5.9%) during August to October in 5 Y old poplar plantations.

Nitrogen fertilization led to an increase in decomposition rate of leaf litter that may be ascribed to increased N content that would meet N requirement of decomposers and produce positive effect on decomposition (Vestgarden, 2001). Similar results on decomposition were reported by Zeng *et al.* (2010). Decay rates of leaf litter are controlled by some factors like substrate quality, climate and quantity and quality of decomposer organi-

-sms (Singh and Sharma, 2007; Li *et al*., 2011). The peak decomposition rate during April to July might be due to enhanced exposure of soil to solar radiation and rainfall thus leading to increase in temperature and moisture. Such climatic conditions provided favourable operating temperature for growth of microbial decomposers like bacteria, thereby leading to enhanced mechanical destruction and fastest leaf litter decay compared to other stages of decomposition (Abugre *et al*., 2011). This peak decay during April to July might also be related to leaching of readily soluble substances and non-lignified carbohydrates (Ibrahima *et al*., 2008). A large fluctuation in leaf litter decay was observed during different months of decomposition with comparatively slower rate during initial 2 months. This might be due to lower temperature for microbes leading to decline in their metabolism and thus decline in decay rate of litter. The lowest rate of decomposition during later stage (August to October) of decomposition might be ascribed to release of resistant fractions like lignin and tannin at advanced stages of litter decomposition (Ibrahima *et al*., 2008).

The slower decomposition of litter under 5 Y compared to 2 Y old plantation might be due to increased intensity of shade with dense canopy of higher aged poplar plantation (5 Y) leading to decline in direct exposure of the site to sunlight, thus leading to decrease in temperature and increase in moisture. These climatic conditions created negative conditions for growth and activity of microbes, thereby reducing decomposition rate of litter (Sunda *et al*., 2018).

Nutrient content in leaf litter

***Nitrogen content*:** Content of N in leaf litter was increased with N fertilization and advancing period of decomposition under 2 and 5 Y old poplar plantations (Fig 1). Fertilization with N_2 had higher content of N in leaf litter as compared to N_1. Among different months of decomposition, the increase in content of N was at highest rate during February to April followed by intermediate increase during May to July, slight decrease during August followed by lowest increase during last 2 months (September-October) under both of the plantations. Interaction effects of N levels and months of study showed that N content was higher during September-October on fertilization with N_2 level under both the poplar ages. In general, both the factors had positive effect on N content of litter with comparatively higher N produced on application of 180 kg N/ha (N_2) during September-October under 5 Y old poplar plantation. This higher N content on fertilization with N might be related to enhanced N content of soil. Greater N content under 5 Y old poplar might be due to declined nutrient losses with lesser decomposition of leaf litter resulting from intense shade, lesser light availability and lower temperature leading to declined microbial activity under dense canopy cover of 5 Y old trees. Variation in N content among different stages of litter decay might be due to variation in temperature and moisture conditions prevailing over time, thereby altering the microbial activity, decomposition rate of litter, N release and thereby its content in litter. These results were in conformity with the earlier findings of Singh (2009), Gaisie *et al*. (2016) and Jijeesh and Seethalakshmi (2016).

Table 1. Quantity of litter (g/bag) remaining in litterbags under 2 and 5-year old poplar plantation at different stages of decomposition with two nitrogen levels

Months	2-year old			5-year old		
	N_1	N_2	Mean	N_1	N_2	Mean
15-Jan	30	30	**30.00**	30	30	**30.00**
15-Feb	27.65	25.57	**26.61**	28.59	26.96	**27.78**
15-Mar	25.71	23.68	**24.70**	26.84	24.72	**25.78**
15-Apr	21.93	20.09	**21.01**	22.56	21.05	**21.81**
15-May	17.84	15.79	**16.82**	18.56	16.75	**17.66**
15-Jun	11.78	9.25	**10.52**	12.75	10.56	**11.66**
15-Jul	8.91	6.32	**7.62**	9.77	7.46	**8.62**
15-Aug	4.76	2.83	**3.80**	5.85	3.28	**4.57**
15-Sep	2.71	1.67	**2.19**	3.17	2.6	**2.89**
15-Oct	1.82	0.9	**1.36**	2.02	1.15	**1.59**
Mean	**15.31**	**13.61**		**16.01**	**14.45**	
CD (P<0.05)	N levels=0.99, Months=2.23, N×M=NS			N levels=0.96, Months=2.15, N×M=NS		

N_1: 120 kg N/ha; N_2: 180 kg N/ha

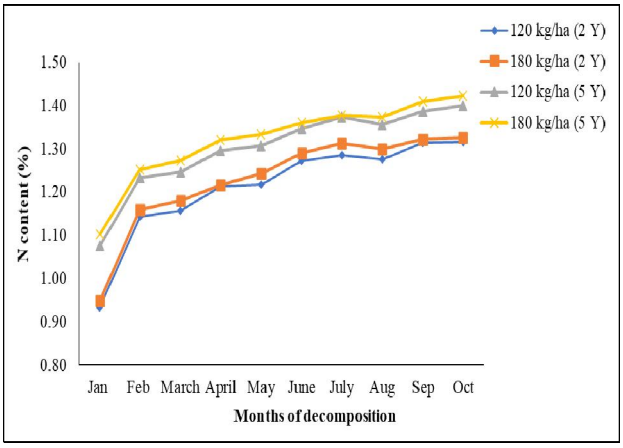


Fig 1. Nitrogen content (%) in decomposing litter under 2 and 5-year old poplar plantations at different stages of decomposition with two nitrogen levels (120 and 180 kg/ha)

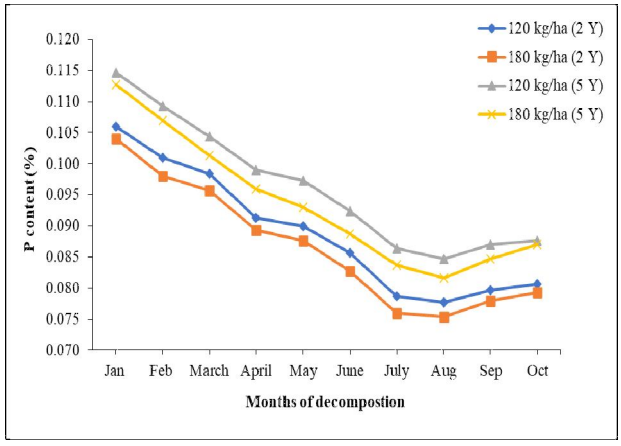


Fig 2. Phosphorus content (%) in decomposing litter under 2 and 5-year old poplar plantations at different stages of decomposition with two nitrogen levels (120 and 180 kg/ha)

Phosphorus content: Variable levels of N fertilizer and different stages of leaf litter decay exhibited decline in content of P in leaf litter under 2 and 5 Y old poplar plantations (Fig 2). Among different stages of decomposition, P content decreased with increasing time indicating the decline at peak rate from January to April followed by intermediate rate during May to July and lowest rate during August followed by increase during September and October under 2 Y old poplars. Similarly under 5 Y old poplars, P content decreased from January to August with comparatively highest rate of decrease during February to April compared to other months of study. Nitrogen fertilization had a negative effect and the decline in P content of poplar leaf litter was higher on fertilization with N_2 compared to N_1 under both 2 and 5 Y old poplar plantations. Interaction effects showed that P content was lower with N_2 fertilizer level during February to April under 2 Y old poplars compared to its content under 5 Y old poplars with same treatments. Time in terms of poplar age also showed a negative effect on P content of litter. The content of P in leaf litter declined to greater extent under 2 Y compared to 5 Y old poplars. Nitrogen fertilization depicted the decline in P content that might be due to additional application of nitrogen (180 kg N/ha) which increased decomposition rate of litter. Increased temperature under 2 Y old poplars and higher microbial activity might have resulted in faster decomposition of litter thereby releasing more P and ultimately decreasing its content in litter. Fastest decrease of P in initial 4 months of decomposition might be ascribed to increased rate of decomposition by increase in temperature of the environment and also due to release of soluble forms of P during these months (Hossain *et al*., 2011).

Potassium content: Potassium content showed a decrease with increasing levels of N and time of study under 2 and 5 Y old poplar plantations (Fig 3). On comparison of different months of decomposition, K content of leaf litter under 2 Y old poplars decreased at a faster rate during February to May, intermediately during May to June and thereafter at slower rate from July to October. Similarly under 5 Y old trees, K content also decreased with advancing stages of decomposition showing higher decrease during February to June as compared to other months. The decline in K content was higher with N_2 level under both 2 and 5 Y old plantations and advancing poplar age from 2 to 5 Y olds. Faster decrease in K content with time might be due to non-structural nature of the element and its higher mobility leading to faster leaching of K. Similar results were reported earlier by Guo and Sims (2002), Singh (2009) and Kaushal *et al.* (2012).

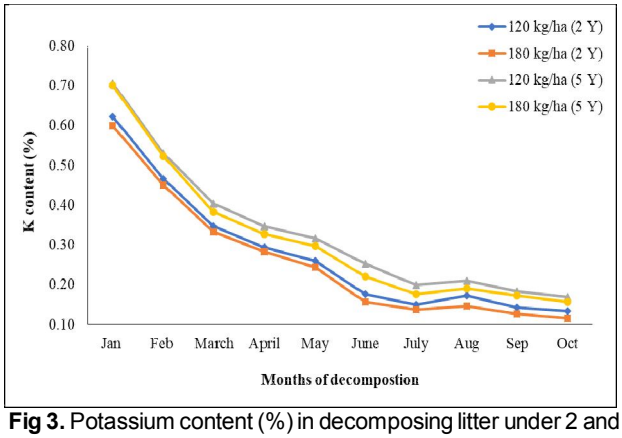


Fig 3. Potassium content (%) in decomposing litter under 2 and 5 year old poplar plantations at different stages of decomposition with two nitrogen levels (120 and 180 kg/ha)

Decomposition and nutrient release from litter

Absolute amount of nutrients in litter bags

***Absolute amount of nitrogen*:** Absolute amount of nitrogen remaining in litterbags showed a significant decline with N fertilization and progressing stages of litter decomposition under 2 and 5 Y old poplars (Table 2). The pattern of remaining N showed decline with increased dose of N fertilizer. It declined about 96% of initial value on fertilization with N_2 under 2 Y old poplars. Among different stages of decomposition, there was a significant increase in remaining N content during February and March but thereafter it showed decrease from April to October. This higher amount of N remaining in bags might be due to initial immobilization of N by microbial population infesting the litter (Dhanya *et al*., 2010). Average N content remaining in 2 Y old poplars was only 6.37% of the initial value during October, whereas in 5 Y old poplars it was 6.85%. The interaction effect was found non-significant with comparatively higher amount remaining with N_1 during initial 2 months under 5 Y old poplars. These results were in accordance with earlier workers (Maharudrappa *et al*., 2000; Isaac and Nair, 2006; Dhanya *et al*., 2010).

***Absolute amount of P*:** Fertilization with N and advancing stages of litter decay showed a significant decline on absolute amount of P in litterbags under 2 and 5 Y old poplar trees (Table 3). Results indicated a decline in P by 97.7% of initial value with N_2 under 2 Y old poplars. Advancement in stages of decomposition from January to October led to significant decrease in remaining P in bags with peak rate decrease (76.2 to 18.7% of initial value) from March to July compared to other time under consideration. Amount of P in bags declined continuously with time and the remaining amount in October was only 3.5% of the initial value under 2 Y old poplars. Under 5 Y old poplars, enhanced time of litter decay led to significant decline in it with maximum average decrease (95.9% of initial value) till October and minimum (12.1% of initial value) till February. Period of litter decay was at its peak during March to July indicating decrease from 77.7 to 21.4% of initial value. Greater decline in P content in bags under 2 Y old canopies with N_2 might be ascribed to higher decomposition rate of litter leading to release of more nutrients from bags (Dhanya *et al*., 2010; Sunda *et al*., 2018).

***Absolute amount of K*:** Absolute amount of K remaining in litterbags decreased significantly with increasing levels of N fertilizer and months of decomposition under 2 and 5 Y old poplar plantations (Table 4). Advancing time of decomposition showed a negative influence on absolute amount of K. It declined from maximum during January to minimum during October with decrease of about 99% of initial value till October in 2 Y old poplars. The greatest level of decrease (45.9 to 9.3%) was observed during March to June. Under 5 Y old poplars, the K content decreased significantly with N fertilization and decrease was higher with N_2 over N_1. Similarly the significant decrease in K content with increasing time period of litter decay was recorded with maximum decline till October. Remaining absolute amount of K in bags reduced at the fastest rate showing decline of 48.2 to13.1% of initial value during March-June in 5 Y old poplars. The interaction was found to be non-significant but with higher amount remaining in N_1 fertilized plots under 5 Y old poplars during March-June. Similar results were observed earlier by Singh (2009) and Sunda *et al.* (2018).

Table 2. Absolute amount of nitrogen (mg/bag) remaining in litterbags under 2 and 5-year old poplar plantations at different stages of decomposition with two nitrogen levels

Months	2-year old			5-year old		
	N_1	N_2	Mean	N_1	N_2	Mean
15-Jan	279.8	285.2	**282.5**	323.5	331.2	**327.3**
15-Feb	304.4	296.5	**300.5**	352.3	338.2	**345.2**
15-Mar	297.3	279.7	**288.5**	334.2	325.0	**329.6**
15-Apr	266.1	244.0	**255.0**	292.9	278.1	**285.5**
15-May	217.0	196.4	**206.7**	242.8	222.8	**232.8**
15-Jun	149.8	119.6	**134.7**	172.2	143.4	**157.8**
15-Jul	114.5	83.1	**98.8**	134.3	102.4	**118.3**
15-Aug	61.2	36.9	**49.1**	79.2	45.0	**62.1**
15-Sep	35.8	22.0	**28.9**	43.7	36.7	**40.2**
15-Oct	24.0	12.0	**18.0**	28.5	16.4	**22.4**
Mean	**175.0**	**157.5**		**200.3**	**182.9**	
CD (P<0.05)	N levels=12.1, Months=27.2, N×M=NS			N levels=13.1, Months=29.3, N×M=NS		

N_1: 120 kg N/ha; N_2: 180 kg N/ha

Table 3. Absolute amount of phosphorus (mg/bag) remaining in litterbags under 2 and 5-year old poplar plantation at different stages of decomposition with two nitrogen levels

Months	2-year old			5-year old		
	N_1	N_2	Mean	N_1	N_2	Mean
15-Jan	31.8	31.2	**31.5**	34.4	33.8	**34.1**
15-Feb	26.9	25.0	**26.0**	31.2	28.8	**30.0**
15-Mar	25.3	22.6	**24.0**	28.0	25.1	**26.5**
15-Apr	20.0	18.0	**19.0**	22.3	20.3	**21.3**
15-May	16.1	13.9	**15.0**	18.0	15.6	**16.8**
15-Jun	10.1	7.6	**8.8**	11.7	9.4	**10.6**
15-Jul	7.0	4.7	**5.9**	8.4	6.3	**7.3**
15-Aug	3.7	2.2	**2.9**	5.0	2.7	**3.8**
15-Sep	2.2	1.3	**1.7**	2.8	2.2	**2.5**
15-Oct	1.5	0.7	**1.1**	1.8	1.0	**1.4**
Mean	**14.5**	**12.7**		**16.4**	**14.5**	
CD (P<0.05)	N levels=0.94, Months=2.10, N×M=NS			N levels=0.87, Months=1.95, N×M=NS		

N_1: 120 kg N/ha; N_2: 180 kg N/ha

Table 4. Absolute amount of potassium (mg/bag) remaining in litterbags under 2 and 5-year old poplar plantation at different stages of decomposition with two nitrogen levels

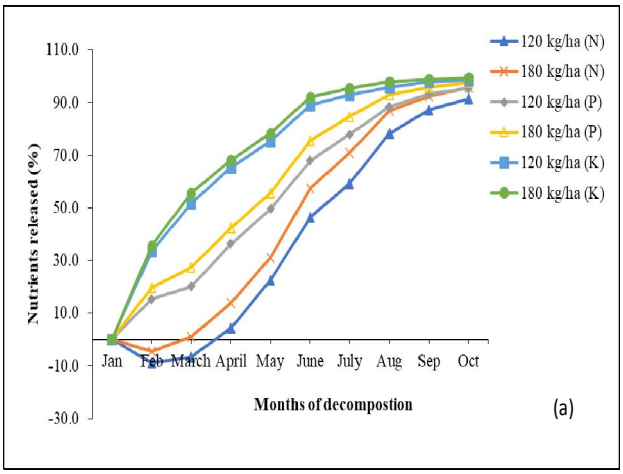
Months	2-year old			5-year old		
	N_1	N_2	Mean	N_1	N_2	Mean
15-Jan	187.3	179.9	**183.6**	212.5	209.8	**211.1**
15-Feb	125.2	114.9	**120.1**	151.0	141.0	**146.0**
15-Mar	89.5	79.4	**84.4**	108.4	95.2	**101.8**
15-Apr	64.0	57.2	**60.6**	77.8	68.3	**73.1**
15-May	46.5	38.7	**42.6**	59.0	49.9	**54.5**
15-Jun	20.5	14.2	**17.3**	32.0	23.1	**27.5**
15-Jul	13.0	8.3	**10.6**	19.9	12.8	**16.3**
15-Aug	8.2	3.9	**6.0**	11.9	6.1	**9.0**
15-Sep	3.8	2.2	**3.0**	5.8	4.6	**5.2**
15-Oct	2.4	1.1	**1.7**	3.5	1.9	**2.7**
Mean	**56.0**	**50.0**		**68.2**	**61.3**	
CD (P<0.05)	N levels=5.48, Months=12.26, N×M=NS			N levels=4.97, Months=11.13 N×M=NS		

N_1: 120 kg N/ha; N_2: 180 kg N/ha

Nutrient release from decomposing litter

Pattern of nutrient (N, P, K) release from decomposing litter was influenced by N levels and months of decomposition under 2 and 5 Y old poplar plantations (Fig 4 a-b). Release of all nutrients showed increase on fertilization with N_2 level compared to N_1. Among different months of decomposition in 2 Y old poplars, the release of N from litter enhanced with release of about 9.2% N during February to April followed by peak rate (55.8%) during May to August and at slower rate thereafter till October (Fig 4 a). Similarly P release also proceeded gradually and almost half (52.6%) of P was released during February to April and only 15% P was released during May to October. Potassium release from litter was highest (66.7%) during February to April followed by intermediate release (17.5%) during May to July and lowest (2.6%) during August to October under 2 Y old poplars. Similarly under 5 Y old poplar plantation, the increased supply of fertilizer N exhibited the positive effect on N, P and K release (Fig 4 b). During different stages of litter decay, the N release was 9.0% during February to April which increased to highest (54.6%) during May to August followed by lowest release in next 2 months. Trend of P release indicated that peak rate of release (50.7%) was observed during February to April and only 14.5% during May to October. Similarly the release of K was maximum (65.7 %) during February to April followed by release at intermediate rate (16.5%) during May to July and lowest (1.9 %) during August to October. Interaction effects showed that nutrient release was greater with application of higher dose of fertilizer N (N_2) with highest release of N during May to August followed

by P and K from February to April under by P and K from February to April under both 2 and 5 Y old poplar plantations. Order of nutrient release from litter was K>P>N. Since the pattern of nutrient release is altered by litter decomposition rate which is being controlled by soil nutrient availability, so fertilization with increased rates of N hastens the process of litter decomposition thereby releasing greater extent of nutrients in soil. Rapid increase in nutrient release during initial period might be due to rapid loss of water-soluble compounds (Gaisie *et al.,* 2016). Pattern of nutrient release over the period indicated that among different months the decrease in N release initially might be due immobilization of N by microbes (Abugre *et al*., 2011). Higher release of P during initial months might be due to its faster release from organic matter, microbial tissues and from soluble forms of P while the slower release at the end might be due to its release from resistant P fractions. Similar pattern of P release was observed by Kumar *et al.* (2001), Semwal *et al*. (2003) and Jijeesh and Seethalakshmi (2016). Highest release of K during initial period might be ascribed to fastest mineralization of K being non-structural element with highly mobile nature and susceptibility to leaching leading to its greater release (Sunda *et al.,* 2018). Among age, the lesser release of nutrients under 5 Y compared to 2 Y old poplars might be explained by the intense shade with dense canopy cover of 5 Y old plantation leading to lower interception of sunlight that resulted in slower decomposition rate of litter and release of nutrients. A very quick release of K from leaf litter of tree species was also observed by Maharudrappa *et al.* (2000) and Dhanya *et al.* (2010).



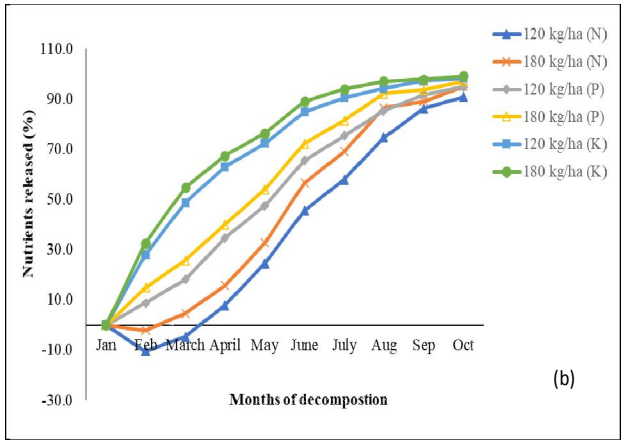


Fig 4 (a-b). Nutrients (N, P and K) released from decomposing litter under (a) 2-year and (b) 5-year old poplar plantations at different stages of decomposition with two nitrogen levels (120 and 180 kg/ha)

Conclusion

The study helped to understand litter decomposition and nutrient release from poplar litter during different months under two levels of nitrogen in different aged poplar plantations. Poplar litter added substantial amount of N, P and K through its decomposition. Release of nutrients was faster with higher application of nitrogen (180 kg/ ha) than the lower dose (120 kg/ha). The release of nutrients was higher in the plantation aged two years than the five years. The nutrient release pattern followed the order K>P>N. Further a huge quantity of litter is added in poplar plantations during winter season and its decomposition is slow owing to lower temperature. It might lead to immobilization of N applied to intercrops during winters. Therefore, such immobilization can be minimized and release of nutrients can be hastened by application of higher quantity of nitrogen to the intercrops sown under poplar plantations. The timely release of nutrients is expected to allow their better utilization by the crops, reduce nutrient losses and enhance use efficiency of the nutrients released from decomposition of litter.

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