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Decomposition and Nitrogen Release Dynamics of Fruit Tree Leaf Litters in Arid Western Rajasthan

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Abstract: Decomposition and nitrogen (N) release dynamics of leaf litters of *Citrus aurontifolia*, *Aegle marmelos* and *Cordia myxa* were studied from June 2010-April 2011 at Research Farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner (Rajasthan). Among the three species, leaf litter of *C. aurontifolia* decomposed more rapidly followed by those of *A. marmelos* and *C. myxa*. About 51% of *C. aurontifolia*, 34% of *A. marmelos* and 21% of *C. myxa* litter disappeared in surface and 59% of *C. aurontifolia*, 36% of *A. marmelos* and 24% of *C. myxa* disappeared in buried condition within 60 days. The decomposition pattern of all the three species could be divided into two phases. The first phase (rainy season from June to November) showed a relatively faster decomposition rate (R) while the second phase (dry and cold season from November to April) showed relatively slower decomposition. The N release in both surface and buried condition followed the order *C. aurontifolia*>*Aegle marmelos*>*Cordia myxa.* The N release in *C. aurontifolia*, *A. marmelos* and *C. myxa* during the cropping season (July to October) was 54.1, 47.6 and 11.4% in surface applied litter and 70.5, 54.7 and 23.1% in buried condition, respectively. The slowest N release was observed in *C. myxa* due to its higher lignin content (45.5%) as compared to *C. aurontifolia* (19.8%) and *A. marmelos* (15.4%).

Key words: *Aegle marmelos, Citrus aurontifolia, Cordia myxa,* litter decomposition, nitrogen release.

In the arid ecosystem of north-western Rajasthan low and erratic rainfall, high temperature and dust storms in summer impose severe restrictions for arable cropping alone (Soni *et al.,* 2006). Growing of location-specific crops in combination with tree/grasses can increase resource use efficiency and replenish soil fertility (Gupta and Gupta, 1993; Soni *et al*., 2007). From the last two decades, a great emphasis is being laid on the development of arid lands through agri-horti, agri-silvi models due to different rooting pattern of components for better utilization of moisture and nutrients. Citrus (*Citrus aurontifolia*), bael (*Aegle marmelos*) and gonda (*Cordia myxa*) are some of the potential fruit trees species under agri-horti systems in partially irrigated arid situation. The foliage biomass produced by these species enhance soil fertility by recycling the nutrients through litter fall, pruning or importing nutrients through biomass transfer systems (Mafongoya *et al*., 1998). Intensive studies on litter dynamics in forest ecosystems have been carried out worldwide (Whitford, 2002; Kemp *et al*., 2003; Yahdjian *et al*., 2006, Bolkhelm *et al*., 1991). But the litter decomposition of fruit tree species grown in farm fields have not received due attention. Currently, no information is available on the litter decomposition of *C. aurontifolia*, *A. marmelos* and *C. myxa*, the three potential fruit tree species of agri-horti systems of western Rajasthan. Hence, the present experiment was carried out to study the litter decomposition and N release pattern of leaf litter of *C. aurontifolia*, *A. marmelos* and *C. myxa* under field conditions.

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Materials and Methods

The study was conducted from June 2010 to April 2011 at Research Farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner, India (latitude 28.03°N, longitude 73.19°E) in an agri-horti system consisting of three fruit trees (*C. aurontifolia*, *A. marmelos* and *C. myxa)* grown under drip system with clusterbean as rainfed intercrop. The average annual rainfall of the region is 275 mm with 57% coefficient of variation. Mean monthly maximum and minimum temperature ranged from 21 to 43°C and 6 to 29°C, respectively, in which the mercury touches 47°C in summer and dipping down to freezing point in winter.

The soil was alkaline, non-saline, loamy sand with soil organic carbon=0.10%, pH=8.3 and EC_2=0.22 dS m^{-1}. The water content at field capacity was 8.1% (w/v). The senescent leaves of three fruit tree species were collected from each tree and were brought to the laboratory for estimation of moisture. Sub samples were oven dried at 70°C to constant weight for further analyses of total carbon (C_{tot}), total nitrogen (N_{tot}), lignin, cellulose and ADF. C_{tot} was analyzed by CHN analyzer, N_{tot} by standard Kjeldahl digestion after acid digestion (Jackson, 1973). Acid detergent fiber (ADF), cellulose and lignin were estimated by method given by Van Soest *et al.* (1991).

Litter decomposition was studied by Litterbag technique (Anderson and Ingram, 1989). Two sets of 50 nylon litterbags (1 mm mesh) of each species containing 20 g leaf litter (dry weight basis) were positioned on surface (placed horizontally at the surface below the tree canopy and fixed with iron nails) and buried condition (placed at 10 cm depth in soil in between the inter row spacing of tree species, which was used for growing clusterbean as a kharif intercrop). These treatments reflect the effect of cultivation and no cultivation. To assess the pattern of decomposition, five litter bags from each species (30 litter bags in all) were retrieved randomly on each sampling date at monthly interval. After removing any extraneous material from litter bags, they were dried at 70°C for 48 hours till constant weight and analyzed for weight loss. Triplicate samples of decomposing litter at each time interval were analyzed for total N by standard methods (Jackson, 1973).

The relative decomposition rates (R) for various species were calculated using the following expression of Gupta and Singh (1981).

$$R = \frac{(\log_e W_0 - \log_e W_1) * 1000}{t_0 - t_1}$$

where, R is mean relative decomposition rate (mg g^{-1} day^{-1}), W_1 is weight (g) at time t_1 and W_0 is weight (g) at time t_0.

Nitrogen release from the decomposing leaf litter of the individual species was derived using the following equation:

$$\text{Nitrogen release (\%)} = [(C_0 \times M_0 - C_t \times M_t)/(C_0 \times M_0)] * 100$$

where, C_0 is the initial concentration of N in leaf litter and C_t is the concentration of the N in the decomposing leaf litter at sampling time t. M_t is the dry weight of decomposed leaf litter at time t, and M_0 is the initial dry weight of the litter.

Results and Discussion

Initial chemistry of leaf litter

Total N concentration in the leaf litter varied from a minimum of 0.93% in *C. myxa* followed by *A. marmelos* (1.66%) to a maximum of 2.17% in *C. aurontifolia* (Table 1). Lignin (45.5%) and cellulose (17.2%) were maximum in the *C. myxa* and minimum in *A. marmelos* (15.4 and 4.7%, respectively). The C:N ratio was also maximum in *C. myxa* (53.1%) followed by *A. marmelos* (25.9%) and lowest in *C. aurontifolia* (22.7%).

Table 1. Initial composition of leaf litter of C. aurontifolia, A. marmelos and C. myxa used in decomposition experiments (Values are mean ±S.E.)

Parameters	*C. aurontifolia*	*A. marmelos*	*C. myxa*
C_{tot} (%)	49.3±0.8	43.0±0.7	49.5±1.3
N_{tot} (%)	2.17±0.04	1.66±0.03	0.93±0.04
C:N ratio	22.7±0.4	25.9±0.7	53.1±0.9
ADF (%)	34.3±0.8	20.1±1.7	62.7±4.1
Lignin (%)	19.8±0.5	15.4±1.3	45.5±2.5
Cellulose (%)	14.4±0.7	4.7±0.4	17.2±2.4

Mass losses of leaf litters

The cumulative mass loss of leaf litters varied significantly with time, species and method of application (Fig. 1). In all the three species, the mass loss decreased after an initial rapid loss. Among the three species, leaf litters of *C. aurontifolia* decomposed more rapidly followed by *A. marmelos* and *C. myxa*. About 51% of *C. aurontifolia*, 34% of *A. marmelos* and 21% of *C. myxa* litter disappeared in surface and 59% of *C. aurontifolia*, 36% of *A. marmelos* and 24% of *C. myxa* disappeared in buried condition within 60 days. The key factors controlling the decomposition rate and nutrient release pattern of leaf litter are its quality viz. lignin content (Palm, 1995), nitrogen (N), C:N ratios (Constantinides and Fownes, 1994) and polyphenols. In general, high C:N ratio and high lignin content result into slow decomposition and nutrient immobilization, whereas low C:N ratio and low lignin content result in fast decomposition and mineralization.

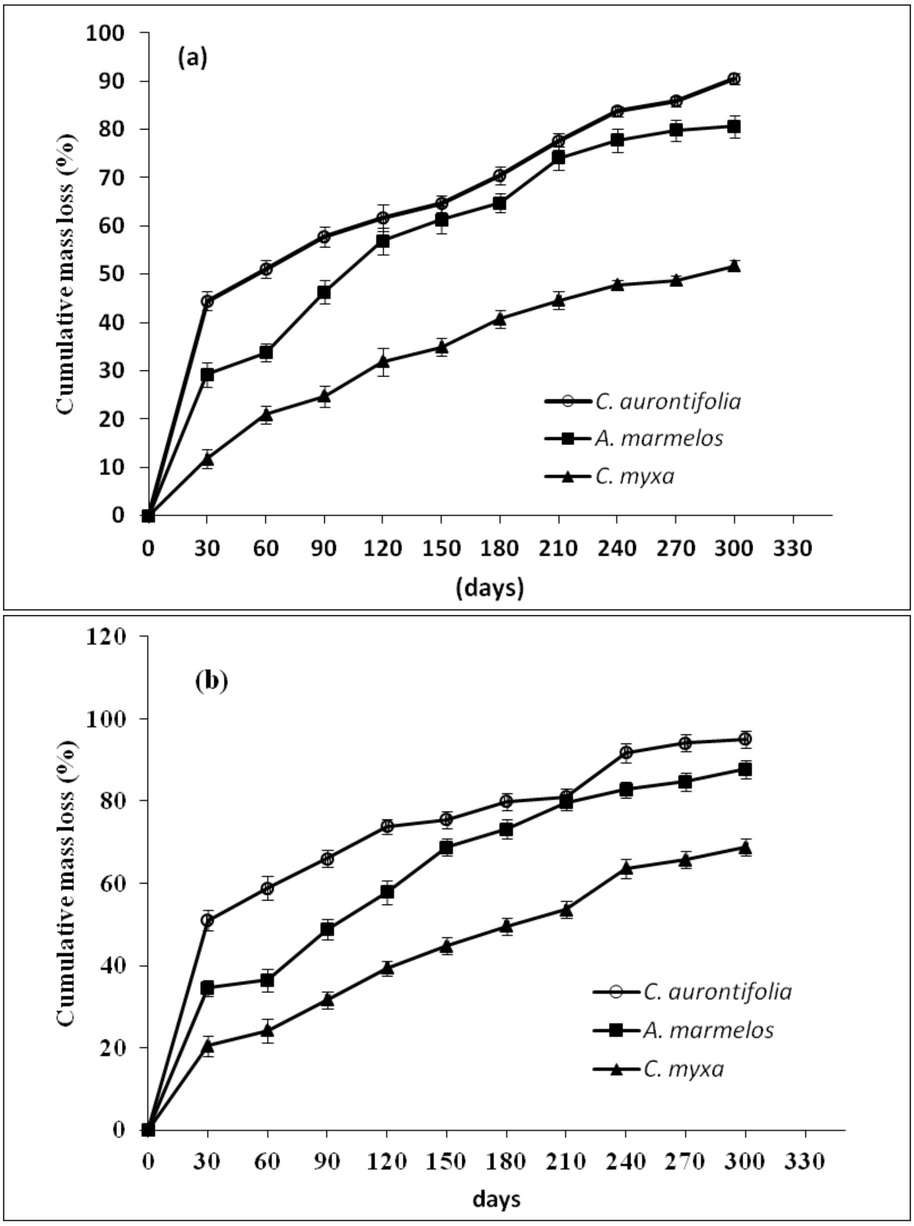

Fig. 1. Cumulative mass loss (%) of leaf litters of three fruit tree species in (a) litterbags deployed at surface and (b) litterbags buried at 10 cm deep in soil (bars represent standard error).

The species with former characteristics are referred as poor quality litter species (Hobbie, 1992), but they play important role as energy sources for microorganisms and also as a carrier of nutrients to soil. Richards (1987) reported that nitrogen exerts a strong influence in the early stages of decomposition. It affects the physiological adaptation of the organisms associated with decomposition. Hence, the leaf litters with high N contents (low C-to-N ratios) decomposes more rapidly, particularly during the early stage of decomposition, than litter with low N contents (Gupta and Singh, 1981; Teklay and Malmer, 2004). In the present study, the N content of *C. aurontifolia* (2.17%) was higher as compared to *A. marmelos* (1.66%) and *C. myxa* (0.93%) which resulted in higher decomposition rate of citrus as compared to the other two species. Melillo *et al*. (1982) reported that lignin content of the litter exerts more control over the rate of decomposition as compared to nitrogen. The high lignin in *C. myxa* (45.5%) bind strongly to organic-N (e.g. amino acids and proteins) in litter, hence making its litter resistant to decomposition (Palm and Sanchez, 1991). The differences in decomposition rates between *C. aurontifolia* and *A. marmelos* litters can be attributed to high N

Table 2. Linear regression between Ln of % remaining mass (Y) with time (X in days) for different litter species after 10 months of decomposition

Method of application	Species	Regression equation	r^2	P
Surface	*C. aurontifolia*	Y = +4.3419 -0.0063 X	0.95	**
	A. marmelos	Y = +4.4406 -0.0053 X	0.98	**
	C. myxa	Y = +4.5099 -0.0022 X	0.98	**
Buried	*C. aurontifolia*	Y = +4.3183 -0.0086 X	0.93	**
	A marmelos	Y = +4.4784 -0.0066 X	0.99	**
	C. myxa	Y = +4.5375 -0.0036 X	0.98	**

content of *C. aurontifolia* because lignin did not differ much between these two litters.

The instantaneous rates of decomposition were calculated as per cent weight loss per day. The highest rate of decomposition was observed during the first month of incubation which was 1.7, 1.1 and 0.7% per day in buried and 1.4, 0.9 and 0.4% per day in surface placed litter of *C. aurontifolia*, *A. marmelos* and *C. myxa*, respectively. The initial rate of litter disappearance in *C. aurontifolia* was more than double as compared to *C. myxa* in both surface and buried condition. The relation between weight loss pattern and time was tested through regression analysis (Fig. 2). The resulting regression equations were given in Table 2. The correlation coefficients describing the remaining mass with time were highly significant ($P<0.01$).

Mean relative decomposition rate (R)

In order to understand the effect of weather variables on decomposition rate, mean relative decomposition rate (R) was calculated for different species (Table 3). The decomposition rate was strongly influenced by climatic conditions and initial chemical composition of the litter (Couteaux *et al.*, 1995). The decomposition pattern could be divided into two phases (Table 3). The first phase (rainy season from June to November) showed a relatively faster decomposition rate of litter, while the second phase (dry and cold season from November to April) showed a steady loss till the end of the decomposition period. The high rate of decomposition in the first phase corresponds with high moisture content of soil due to good amount of rainfall received in current year. A total of 383 mm rainfall was received from June to November, 2010. The effect of moisture, promoting the microbial growth may explain the increased rate of weight loss during the rainy season (Gupta and Singh, 1981). Similar finding has been reported by Hood (2001) who observed that the plant dry matter decreased significantly with increase in soil temperature and increased with increasing moisture.

The relative decomposition rate during the study period followed the order *C. aurontifolia*> *A. marmelos*>*C. myxa* in both buried and surface placed litters. The mean R values in all the three species were higher in buried condition than surface placed litters. The mean R values for the entire study period were 10.0, 7.01 and 3.88 mg g^{-1} day^{-1} in buried and 7.85, 5.87 and 2.42 mg g^{-1} day^{-1} in surface applied litters of *C. aurontifolia*, *A. marmelos* and *C. myxa*, respectively. The higher decomposition rate of buried litter may be ascribed to increased activity of soil fauna (Parker *et al.*, 1984) as compared to surface litter. The larger surface area of the litter accessible to microorganisms may also have contributed to

Table 3. Mean relative decomposition rates (R in mg g^{-1} day^{-1}) of C. aurontifolia, A. marmelos and C. myxa litters at different sampling intervals and for total study period

Species	Rainy season (June 2010-November 2010)	Dry and cold season (November 2010-April 2011)	Total study period (June 2010-April 2011)
Surface			
C. aurontifolia	6.92±0.50	4.19±0.73	7.85±0.55
A. marmelos	6.33±0.49	4.66±0.41	5.47±0.42
C. myxa	2.87±0.18	2.66±0.10	2.42±0.08
Buried			
C. aurontifolia	9.38±0.66	5.93±1.54	10.00±0.94
A. marmelos	7.76±0.46	5.96±0.81	7.01±0.63
C. myxa	3.96±0.25	3.04± 0.38	3.88±0.22

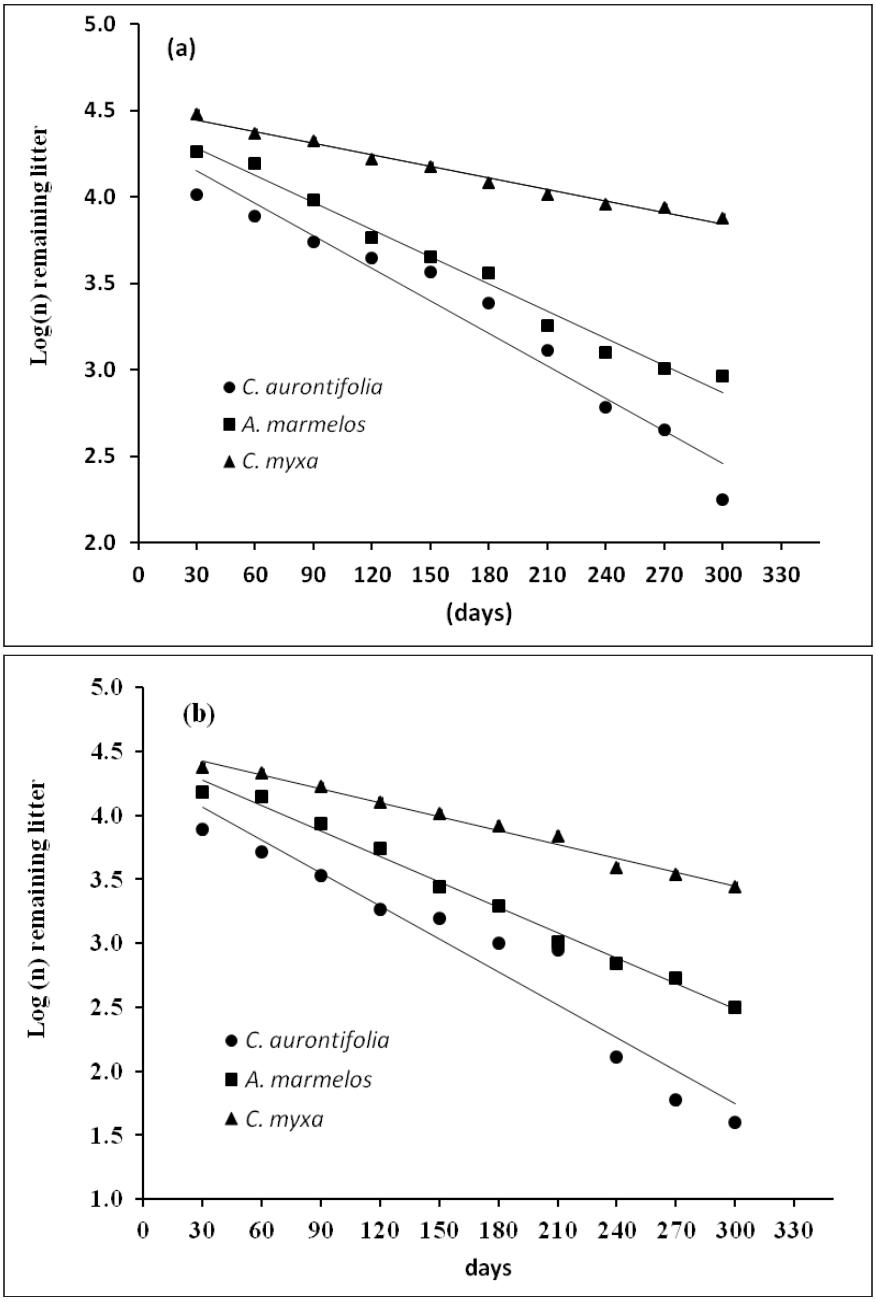

Fig. 2. Regression lines showing the mass loss pattern of different leaf litters of three fruit species with time in (a) litterbags deployed at surface and (b) litterbags buried at 10 cm deep in soil.

the higher decomposition rate observed in the buried litterbags, which is consistent with the results of Bayala *et al*. (2005). Another possible reason for higher rate of decomposition of buried litter was the moderate moisture and temperature of the surrounding soils of the buried litterbags, which are conducive for the growth of micro-fauna and flora resulting in increased decomposition (Gnankambary *et al*., 2008).

Nitrogen release during litter decomposition

The release of N was species specific and mode of their application. The *C. aurontifolia* released the nutrients rapidly as compared to *A. marmelos* and *C. myxa*. The N release in *C. aurontifolia*, *A. marmelos* and *C. myxa* during the cropping season (July to October) was 54.1, 47.6 and 11.4% in surface applied and 70.5, 54.7 and 23.1% in buried condition, respectively. The N

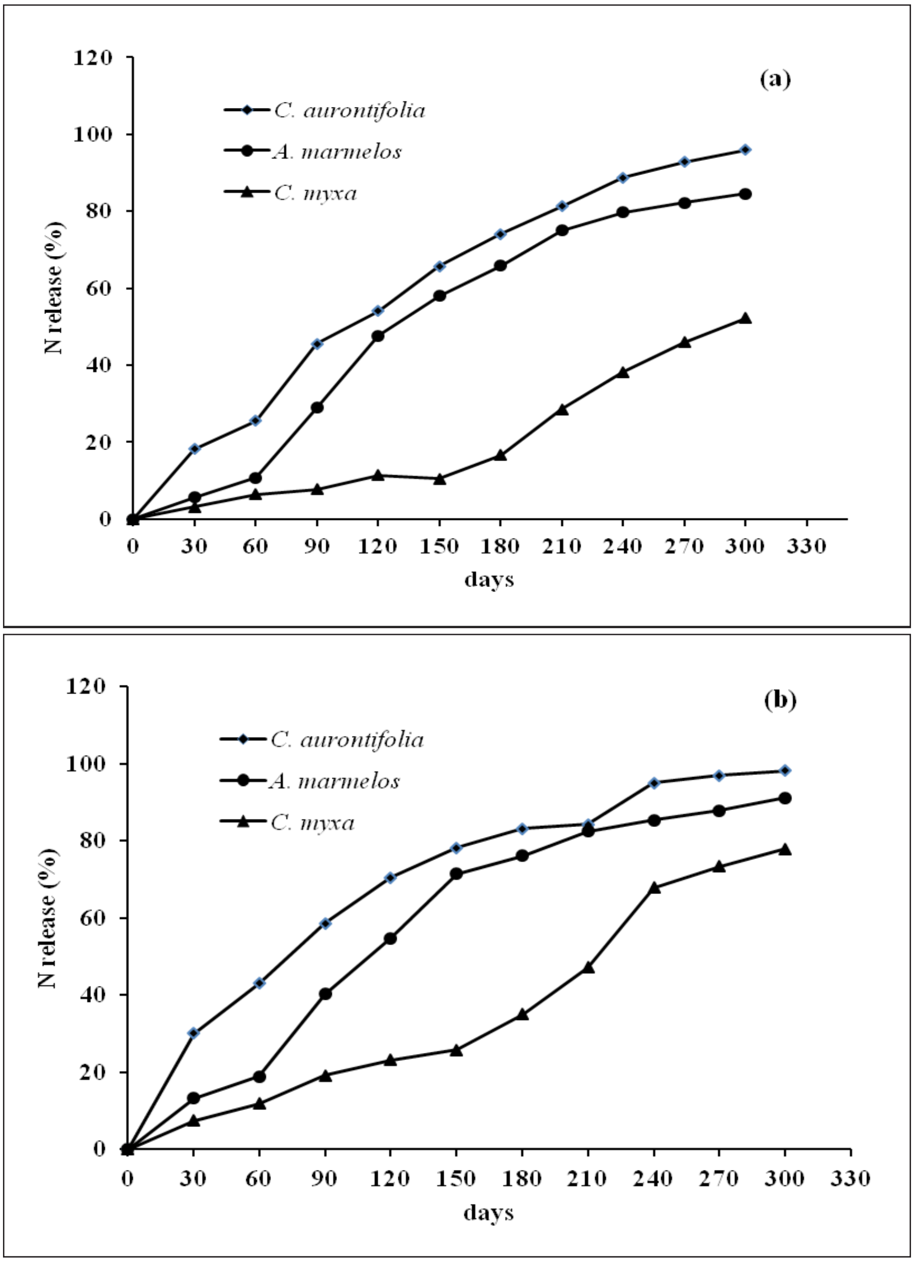

Fig. 3. Cumulative N release (%) of leaf litters of three fruit tree species in (a) litterbags deployed at surface and (b) litterbags buried at 10 cm deep in soil.

release in *C. myxa* upto 150 days was very slow in both surface and buried litters. The slowest nitrogen release in *C. myxa* could be ascribed to its slow decomposition due to higher lignin content (45.8%) as compared to *C. aurontifolia* (19.8%) and *A. marmelos* (15.3%). The study suggested that leaf litters of *C. aurontifolia* and *A. marmelos* constitute comparatively good sources of readily available N and they could be suitable for meeting partial nitrogen requirement by intercrops. With the slow decay of the *C. myxa* litter, it is worthy to be used for long term organic matter build up in arid soils.

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