Environmental Resources Research
Vol. 2, No. 1, 2014

GUASNR

Litter Production Dynamics in Relation to Climatic Factors in Tree Plantations

E. Sayad[*1], S. Gholami[1], M.H. Salehe-Shooshtari[2]

[1] Assistant Professor, Natural Resources Department, Razi University
[2] M.Sc Graduate, Instructor, Agricultural and Natural Resources Research Institute of Khuzestan, Ahvaz

Received: September 2013 Accepted: December 2013

Abstract

We studied litterfall dynamics of 14 to 15 year old tree plantations in Dez River floodplain. The plantations consist of *Populus euphratica* Oliv., *Eucalyptus camaldulensis* Dehnh., *E. microtheca* F. Muell, *Acacia farnesiana* (L.) Willd., *A. salicina* Lindl., *A. saligna* (Labill.) H. Wendl., *A. stenophylla* Benth and *Dalbergia sissoo* Roxb. Litterfall was different between the tree species, and leaf litter fall was the dominant part, while reproductive and woody parts had considerable shares in some species. The results also showed that most of the litterfall from evergreen and deciduous trees occurred in June and October, respectively. Day length and maximum and minimum temperature controlled the litterfall of some species. Totally, we could state that although leaf litter is the main part of the litterfall, reproductive and woody parts have also considerable amounts in some species e.g. *Eucalyptus* species. Also, the obvious differences in litterfall fractions between the different species confirmed that the litterfall fractions should be considered in studying nutrient cycling.

Keywords: Litter Production, Litterfall dynamics, Climatic factor, Plantation

[*]Corresponding author; ehsansaiad@yahoo.com

1. Introduction

Tree plantation is a widespread activity for rehabilitating the degraded ecosystems all over the world. Establishing sustainable plantation strongly depends on species selection (West, 2006). Having good knowledge of different ecological characteristics of the tree species is essential for suitable selection. On the other hand, understanding the ecological properties of these ecosystems could help us to avoid failures, minimize ecological damage, and optimize the use of soil, water, and energy resources (Cuevas and Lugo, 1998). Also, tree plantation could provide biomass production, biodiversity (Rhoades and Binkley, 1996) and increase soil carbon (Turner *et al.,* 2005). Farthermore, because of the environmental constrains in arid and semi-arid areas (Maestre and Cortina, 2004) species selection needs more exact knowledge.

Different aspects of nutrient cycling should be considered in species selection (Cuevas and Lugo, 1998). Also, it is mentioned that the management of forest plantation should be based on nutrient cycling (Montagnini, 2000; Guo and Sims, 2001, 2002). Litterfall is the fundamental process in nutrient cycling and also the main means for transfer of organic matter and mineral elements from vegetation to the soil surface (Anderson *et al.*, 2003; Pandey *et al.,* 2007; Barlow *et al.*, 2007; Wang *et al.*, 2008; Oladoye *et al.*, 2010). Tree species differ widely in their litterfall and consequently they could change the ecosystem differently (Cuevas and Lugo, 1998, Parrotta, 1999, Reich *et al.*, 2005). Therefore, litterfall dynamics should be studied before tree introduction to any new area.

The other factor that should be considered is the timing of mass return through litterfall to the forest floor (Wang *et al.,* 2008). Good knowledge of this factor is important for plantation management (Cuevas and Lugo, 1998, Gonzalez-Monoz, 2013). Until recently, not many studies were completed on litter production and dynamics of tree plantations in riparian ecosystems in semi-arid climates.

In this study we aim to determine to what extent trees differ in their litterfall rates and patterns. The results of these analyses advance our understanding of forest plantation ecology in riparian areas and help land managers in selection and management of tree species for plantations. We posed the following questions: (1) what are the rates and patterns of litterfall of species with different phyto-geographical origins and phenological characteristics when grown under similar edaphic and climatic conditions? (2) Is there any difference in the rate and patterns of litterfall of nitrogen fixing trees and non-nitrogen fixing trees? (3) What climatic factors regulate leaf senescence and the temporal patterns of litterfall in these tree species?

2. Materials and methods

Study site

The research was carried out in the Dez river floodplain in southwestern Iran (32°24'N, 48°25'E). Experimental plots were located at an altitude of 143 m above sea level. Annual average rainfall is about 325.8 mm, with about 8 months of dry season from April to November. Average monthly temperatures ranges from 11.5 °C to 34.7°C. Soil type of the study site according to US Soil taxonomy classification is Entisols (Soil Survey Staff, 2006).

The monoculture plantations were established in randomized complete block design in 1992 with three blocks along the river. Tree spacing within plantations was 3m×3m in 27m×30m plots. The experiment was included ten species at the beginning. The species were *Populus euphratica*, *Eucalyptus camaldulensis*, *E. microtheca*, *Acacia farnesiana*, *A. salicina*, *A. saligna*, *A. stenophylla*, *A. victoriae*, *Dalbergia sissoo* and *Leucaena leucocephala*. The three first species are non-nitrogen fixing and the others are nitrogen fixing trees. In 2006, L. *leucocephala* and *A. victoriae* did not survive more and the study was carried out with the remaining species. Some properties of the tree plantations are reported in Table 1.

Table 1. Survival, height and diameter of tree species in the plantations. The values are means. Source: Sayad *et al.* (2012)

Plantations	Survival (%)	Height (m)	Diameter (cm)
P. euphratica	57.77	11.35	12
E. camaldulensis	92.22	18.45	28
E. microtheca	89.25	12.96	24
A. farnesiana	89.99	6.65	6
A.saligna	47.96	7.95	11
A. stenophylla	77.40	9.35	12
A. salicina	86.29	13.80	16
D. sissoo	76.66	13.70	24

Litterfall

Litterfall was collected from the beginning of November 2006 and extended to November 2007 at bi-weekly intervals. Two litter traps, each $0.25m^2$, were randomly erected in each plot. Each trap consisted of 2 mm mesh nylon netting (on a wooden frame) suspended from a wire hoop and held 20 cm above the ground. Litter was separated to leaves, reproductive parts and woody parts in each plot at each gathering time. Litter fractions were dried at 65°C to estimate dry mass.

Climatic factors

In order to find the regulating factor of litterfall we gathered climatic factors during the experiment. The factors were day light duration (hours), Sunrise time (hours), Sunset time (hours), minimum air temperature (°C), maximum air temperature (ºC), mean air temperature (ºC) and precipitation (mm). All of the climatic data were obtained from Safi abad Dezful synoptic weather station (Fig. 1).

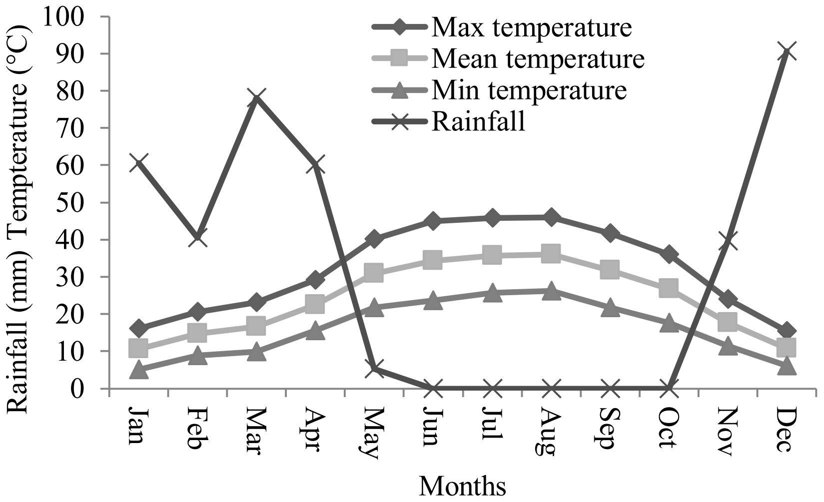


Figure 1. Monthly rainfall (mm), Max, Mean and Min Temperature (°C) during the year of the study.

Statistical Analyses

Litter production was compared between the species and the two groups using general linear analysis of variance (ANOVA) tests. The Pearson correlations were used for finding the relationships between litter fractions dynamics and climatic factors. Normality and homogeneity of variance of the data were checked for all analyses. All statistical analyses were completed using SAS 9 software.

3.Results and discussion

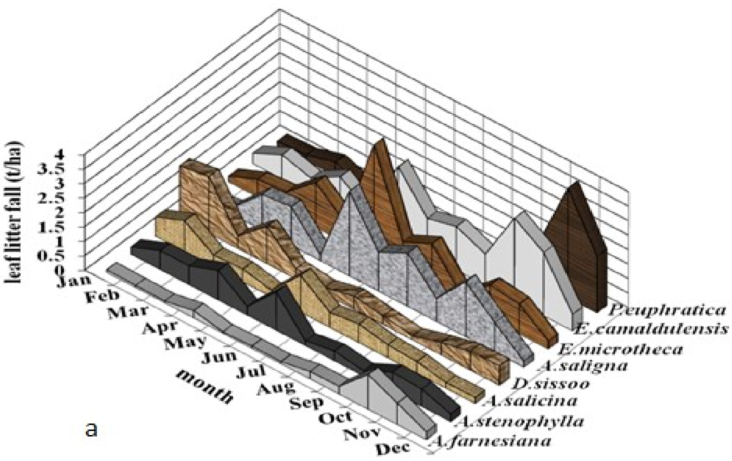
In all the plantations leaf litter was the highest fraction of litterfall and woody parts was the lowest except in *Eucalyptus* plantations. Leaf litterfall and woody parts were significantly different among the plantations while reproductive parts were not significantly different. *E. camaldulensis* and *A. farnesiana* had the highest and lowest total litterfall and leaf litterfall, respectively. Woody parts were significantly higher in *E. camaldulensis* plantations, intermediate in the *E. microtheca* and lowest in the other species. The highest amount of reproductive parts was observed in *E. microtheca* while *D. sissoo* had the lowest. The comparison of the two groups showed that leaves and woody parts fractions and total mass were significantly higher under non nitrogen fixing trees (Tab. 2).

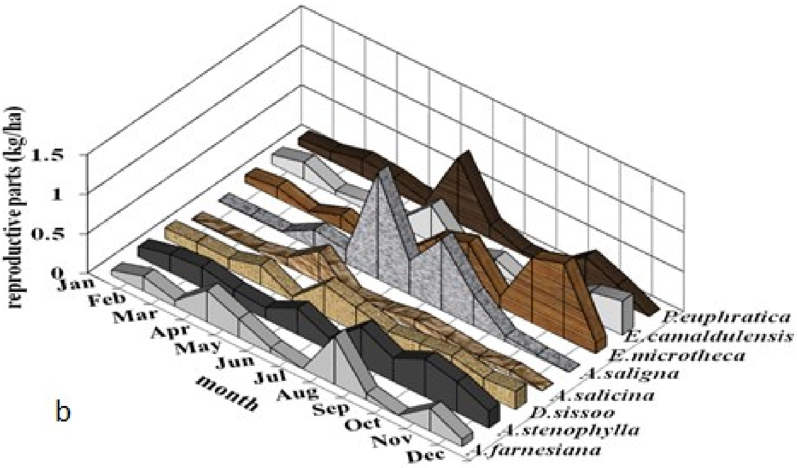
Table 2. Mass of total litterfall and litter fractions of different species in the plantations. The values are mean (S.E.) [a].

Plantations	*P. euphratica*	*E. camaldulensis*	*E. microtheca*	*A. farnesiana*	*saligna.A*	*A. stenophylla*	*A. salicina*	*D. sissoo*	ANOVA[b] Block	ANOVA[b] Species	N Fixing Tree	Non-N Fixing Tree	ANOVA[b] Block	ANOVA[b] Two groups
Mass (t/ha/yr)														
Leaves	8.5bc (1.3)	15.2a (2.3)	13.0ab (1.6)	3.4c (0.4)	13.1ab (2.3)	6.4c (0.7)	6.4c (1.6)	8.6bc (2.7)	ns	**	7.6 (1.1)	12.2 (1.3)	ns	*
Reproductive parts	2.3 (0.2)	2.2 (0.2)	3.6 (1.6)	2.1 (0.6)	3.6 (0.8)	3.3 (1.0)	2.6 (0.5)	0.9 (0.2)	ns	ns	2.4 (0.4)	2.7 (0.5)	ns	ns
Woody parts	0.2c (0.0)	12.8a (0.8)	3.5b (1.3)	0.3c (0.1)	0.1c (0.0)	0.5c (0.1)	0.5c (0.2)	0.38c (0.1)	ns	**	0.4 (0.1)	5.5 (1.9)	ns	**
Total	10.95cd (1.53)	30.2a (2.97)	20.67b (4.50)	5.76d (0.50)	16.8bc (3.14)	10.15cd (1.63)	9.53cd (2.15)	9.95cd (2.59)	ns	**	10.44 (1.26)	20.44 (3.21)	ns	**

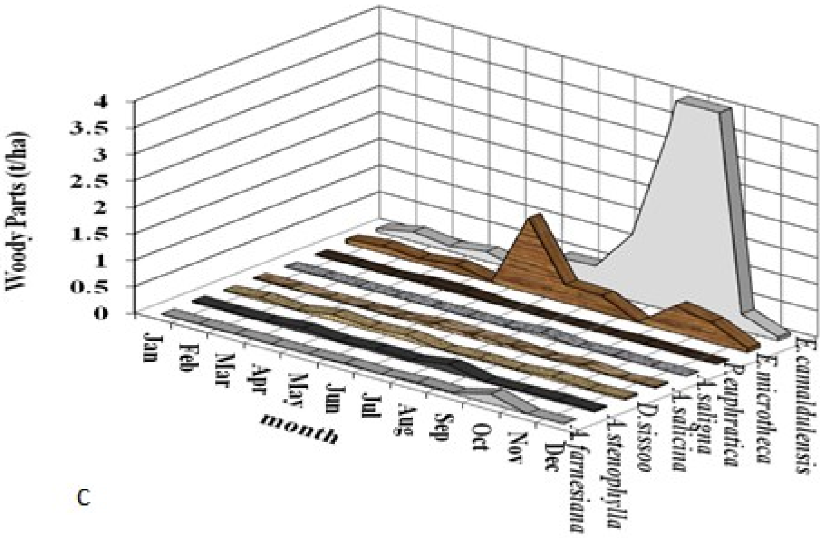
[a] Different letters following values indicate the differences based on Duncan.
[b] ANOVA results: ns = treatment effect not significant, * = P<0.05, ** = P<0.01

The leaf litterfall dynamics of different species showed that most of the litterfall from deciduous *(P. euphratica*, *A. farnesiana* and *D. sissoo*) and evergreen species (the other species) was occurred in October and June, respectively. We did not find any relationships between leaf litterfall dynamics and the nitrogen fixation (Fig. 2A). As we did not separate the flowers from fruits in litterfall, two peaks in litterfall dynamics are observed that show the flower and fruit shedding time, respectively (Fig. 2B). Woody parts shedding rate and pattern of Eucalyptus species were different from the other species. This difference could be the results of their bark shedding that begins from June and extends to November (Fig. 2C).





b



c

Figure 2. Litterfall dynamics of different tree plantations in a year round period. A: leaf litterfall, B: reproductive parts and C: woody parts.

Among all of the tree species planted in the study site, *P. euphratica*, *E. microtheca*, *A. saligna* and *D. sissoo* leaf litterfall were significantly correlated with the climatic factors. Leaf litterfall of *P. euphratica* and *E. microtheca* were respectively correlated with Sunset and sunrise times while leaf litterfall of *A. saligna* was positively correlated with maximum temperature. Litterfall from reproductive parts of *A. saligna* was positively correlated with daylight duration. Woody parts litterfall of *E. camaldulensis* was negatively correlated with precipitation. Woody parts and leaf litterfall fractions of *D. sissoo* were correlated with maximum temperature while litterfall from reproductive parts were negatively correlated with Sunrise time (Tab. 3).

Table 3. The associations of species litterfall fractions dynamics (t/ha/month) with the climatic factors are shown as regression equations and correlation coefficients.

Species	Equation	r^a
P. euphratica	Leaf litterfall = 33.616 – 1.547 (Sun Set time)	- 0.801**
E. camaldulensis	Woody parts litterfall = 6.616 – 0.030 (Precipitation)	- 0.606*
E. microtheca	Leaf litterfall = 5879.203 – 793.547 (Sun raise time)	- 0.619*
A. saligna	Leaf litterfall = 45.343 (Maximum temperature) – 352.211	0.626*
A. saligna	Reproductive parts litterfall = 210.195 (Day light duration) – 2226.318	0.743**
D. sissoo	Leaf litterfall = 7.925 – 0.052 (Maximum temperature)	- 0.752**
D. sissoo	Reproductive parts litterfall = 12.396 – 1.421 (Sun raise time)	- 0.756**
D. sissoo	Woody parts litterfall = 1.446 (Maximum temperature) – 14.092	0.632**

[a] correlation coefficients significance at *=P<0.05, **=P<0.01.

As we found in our plantations, Attignon *et al.* (2004) noticed leaf litter as the dominant part of litterfall (Tab. 2). Litterfall is a major source of organic matter and nutrient return into the soil (Pandey *et al.,* 2007). Therefore, it could be concluded that nutrients cycling is higher under trees with higher litterfall. More research on nutrient return is required. As shedding of woody parts is considerably higher under *Eucalyptus* species, this species requires further attention in studies of nutrient return to soil.

The timing of leaf litterfall could help us separate deciduous species from evergreens (Fig. 2A). The results showed that the highest leaf litterfall of *Eucalyptus* species were in dry season whereas, Barlow *et al.* (2007) reported that *Eucalyptus urphylla* shed most of their leaves in wet season. As leaf litterfall timing was different among the species, we could use this factor together with the amounts of nutrient return as an important item in selecting species for plantation. On the other hand, litterfall timing in relation to litter decomposition will help us know the nutrient return potential of species that is important in changing the soil fertility and consequently forest composition (Hobbie, 1992).

The litterfall fractions of some species were regulated with day length duration and maximum temperature. Cuevas and Lugo (1998) reported similar results about some species whereas; Barlow *et al.* (2007) and Devi and Yadava (2010) reported correlation of leaf litterfall of *Eucalyptus urphylla* with rainfall. Also Pandey *et al.* (2007) found negative correlation of *Quercus serrata* leaf litterfall with minimum air temperature. Therefore, we suggest the use of the mentioned climatic factors as the most important ones in litterfall studies. However, it should be considered that as the climatic factors are somehow changeable through the years it needs further studies in different years. These results are important in gathering seeds and predicting seed rain and litterfall of different species.

4. Conclusion

Our study aimed at litterfall dynamics of 14 to 15 year old tree plantations in Dez River floodplain. The plantations consisted of *Populus euphratica* Oliv., *Eucalyptus camaldulensis* Dehnh., *E. microtheca* F. Muell, *Acacia farnesiana* (L.) Willd., *A. salicina* Lindl., *A. saligna* (Labill.) H. Wendl., *A. stenophylla* Benth and *Dalbergia sissoo* Roxb. We found that although leaf litter is the dominant part of litterfall, reproductive and woody parts share also considerable amounts in some species e.g. woody parts in *Eucalyptus* species. Therefore, this fact should be considered in nutrient return to soil. Our results help us predict the effects of these trees on soil but supplementary researches on nutrient return and litter decomposition is also required. Consequently we can use the litterfall dynamics and its timing in selecting the tree species for rehabilitating ecosystems.

References

Anderson, D.C., Nelson, S.M., and Binkley, D. 2003. Flood flows, leaf breakdown, and plant-available nitrogen on a dryland river floodplain. Wetlands. 23(1): 180-189.

Attignon, S.E., Weibel, D., Lachat, T., Sinsin, B., Nagel, P., and Peveling, R. 2004. Leaf litter breakdown in natural and plantation forests of the Lama Forest reserve in Benin. Applied Soil Ecology. 27: 109–124.

Barlow, J., Toby, A.G., Leandro, V.F., and Carlos, A.P. 2007. Litter fall and decomposition in primary, secondary and plantation forests in the Brazilian Amazon. Forest Ecology Management. 247: 91-97.

Bijayalaxmi Devi, N., and Yadava, P.S. 2010. Influence of climate and litter quality on litter decomposition and nutrient release in sub-tropical forest of Northeast India. Journal of Forestry Research. 21(2): 143−150.

Cuevas, E., and Lugo, A.E. 1998. Dynamics of organic matter and nutrient return from litter fall in stands of ten tropical tree plantation species. Forest Ecology Management. 112: 263-279.

Gonzalez-Munoz, N., Castro-Díez, P., and Parker, I.M. 2013. Differences in nitrogen use strategies between native and exotic tree species: predicting impacts on invaded ecosystems. Plant Soil. 363:319–329.

Guo, L.B., and Sims, R.E.H. 2001. Eucalypt litter decomposition and nutrient release under a short rotation forest regime and effluent irrigation treatments in New Zealand I. External effects. Soil Biology and Biochemistry. 33: 1381-1388.

Guo, L.B., and Sims, R.E.H. 2002. Eucalypt litter decomposition and nutrient release under a short rotation forest regime and effluent irrigation treatments in New Zealand I. internal effects. Soil Biology and Biochemistry. 34: 913-922.

Hobbie, S.E. 1992. Effects of plant species on nutrient cycling. Trends in Ecology and Evolution. 7: 336-339.

Maestre, F., and Cortina, J. 2004. Are Pinus halepensis plantations useful as a restoration tool in semiarid Mediterranean areas. Forest Ecology Management. 198: 303–317.

Montagnini, F. 2000. Accumulation in above – ground biomass and soil storage of mineral nutrients in pure and mixed plantations in a humid tropical lowland. Forest Ecology Management. 134: 257-270.

Oladoye, A.O., Ola-Adams, B.A., and Adedire, M.O. 2010. Litterfall dynamics in Leucaena leucocephala (Lam) de wit plantation in the Nigerian derived savanna. ARPN journal of Agricultur Biology Science. 2(5): 31-38.

Pandey, R.R., Sharma, G., Tripathi, S.K., and Singh, A.K. 2007. Litterfall, litter decomposition and nutrient dynamics in a subtropical natural oak forest and managed plantation in northeastern India. Forest Ecology Management. 240: 96–104.

Parrotta, J.A. 1999. Productivity, nutrient cycling, and succession in single- and mixed-species plantations of *Casuarina equisetifolia, Eucalyptus robusta* and *Leucaena leucocephala* in Puerto Rico. Forest Ecology and Management. 12: 45-77.

Reich, P.B., Oleksyn, J., Modrzynski, J., Mrozinski, P., Hobbie, S.E., Eissenstat, D.M., Chorover, J., Chadwick, O. A., Hale, C.M., and Tjoelker, M.G. 2005. Linking litter calcium, earthworms and soil properties: a common garden test with 14 tree species. Ecology letters. 8: 811-818.

Rhoades, C., and Binkley, D. 1996. Factors influencing decline in soil pH in Hawaiian *Eucalyptus* and *Albizia* plantations. Forest Ecology and Management. 80: 47-56.

Sayad, E., Hosseini, S.M., Hosseini, V., and Salehe-Shooshtari, M.H. 2012. Soil macrofauna in relation to soil and leaf litter properties in tree plantations. Journal of forest science. 58 (4): 170–180.

Soil Survey Staff, 2006. Keys to Soil Taxonomy, United State Department of Agriculture Natural Resource Conservation Service. 700pp.

Turner, J., Lambert, M.J., and Johnson, D.W. 2005. Experience with patterns of change in soil carbon resulting from forest plantation establishment in eastern Australia. Forest Ecology and Management. 220: 259-269.

Wang, Q., Wang, S., and Huang, Y. 2008. Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern Chaina, Forest Ecology and Management. 255: 1210-1218.

West, P.W. 2006. Growing plantation forests. Springer. 304pp.

Zou, X. 1993. Species effects on earthworm density in tropical tree plantations in Hawaii. Biology Forest Soils. 15: 35–38.