EFFECTS ON SEASONALITY OF LEAF FALL AND LITTER PRODUCTION OF SAL (*Shorea robusta Gaertn.f.*) IN RESPONSE TO TREE MORTALITY

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ABSTRACT

Mortality of trees is a global phenomenon reported from boreal, temperate and tropical forests. The study was conducted in Barkot Range (Moist Deciduous Forest, Dehradun Forest Division) of Uttarakhand. In the interiors of the forest large scale mortality of the Sal trees occurred with typical dieback of the crown. The paper evaluates changes in litter production and seasonal pattern of leaf fall of Sal with respect to Sal mortality in stressed forest ecosystem. The results conclude that the amount of Sal litter in the mortality site (MS) is significantly less than the non-mortality site (NMS). Reduced litterfall, reduced growth and suspension of seed production; increased longevity of leaves and slower replacement of leaves; greater translocation of nutrients especially nitrogen and potassium is an adaptation to conserve mineral nutrients in response to microclimatic changes in the mortality site, affected by anthropogenic disturbances in the forest corridor.

Keywords: *Disturbances; forest corridor; litter fall; microclimate; Sal mortality; stress*

INTRODUCTION

The stability of the forest corridor and the overall health of the forests are deeply related. Disturbances and fragmentation in the corridor have a direct bearing on the structure and functioning of the system through changes in microclimate. The drastic changes in terms of forest cover and thus change in microenvironment has important implications on the structure, biogeochemical cycling, net ecosystem productivity, litterfall and its decomposition, N mineralisation, conservation strategies of the regional forest (Xuluc-Tolosa et al. 2003, Yadav et al. 2008, Fahrig 2013). The magnitude of the edge effect on various structural and functional ecosystem attributes and the distance the effect penetrates into the forest depends on the land use pattern (roads, agriculture, plantation etc.). Similar microclimatic changes in the interiors of the forest influenced by anthropogenic disturbances in the forest corridor have resulted in mortality of *Sal* (*Shorea robusta* Gaertn.f.) in the Barkot Range of Dehradun Forest Division of Uttarakhand. This study was designed to examine the probable cause(s) of mortality of *Sal* trees in the Barkot Range, Dehradun. During the investigations it was observed that 87.5% of the total *Sal* trees in the mortality site were either partially dead or dead. The diameter class most affected i.e. with large number of dead and dying *Sal* trees was 20-40 cm. The predisposing stress factor for *Sal* mortality in the Barkot forest had been removal of forest cover or corridor. The forest area had been subjected to fragmentation by biotic interference (human) especially through change in land use pattern (Chauhan 2001, Negi et al. 2002). The anthropogenic disturbances have facilitated canopy openings in the interiors of the forest, promoted the invasion of successional species in the canopy gaps and increased the heterogeneity of these *Sal* forests (Kukreti and Negi 2004, Gautam et al. 2008).

Litter Production plays a very important role in the dynamics of terrestrial ecosystem especially through nutrient circulation between plant and soil as well as moisture retention. Litterfall is the main input of organic matter and nutrients in the soil being proportional to primary productivity in natural forest. The amount and nature of litter fall is one of the major processes of the ecosystem in determining the type of cycling of nutrients in forest ecosystems. Therefore, the litter fall may be regarded as one of the most useful criterions for the assessment of the changes undergone by disturbed ecosystems. The ecology related to litter and forest floor in forest ecosystems emphasise their role in carbon balance, nutrient cycling and soil health. It is thus essential to measure the amount of forest floor and litterfall (Berg 2000, Wang et al. 2008). Despite extensive litter studies in tropical forest ecosystems (Visalakshi 1993, Pandey et al. 2006, Waring 2012), studies on litter dynamics in disturbed forests especially in reference to tree mortality is very limited. The paper evaluates effects of stress on annual *Sal* litter production and seasonal pattern of leaf fall with respect to *Sal* mortality to further analyse the influence of the forest disturbances on the nutrient cycling of *Sal*.

MATERIALS AND METHODS

Study Area

Barkot Forest Range (Dehradun Forest Division) lies between 30^0 02’ to 30^0 12’ N Latitude and 78^0 07’ to 78^0 20’ E Longitude. It has an altitude of 340-560 m above sea level. Major forest types in the study area are Moist Bhabar Dun Sal and West Gangetic Moist Deciduous Forests (Champion and Seth 1968).

Soil was brown in colour, acidic to neutral in reaction and sandy loam to fine loamy in texture. The mean annual temperature recorded in the Barkot Range during the study period was 22.6^0C and the total annual rainfall was 1718.3 mm with bulk of the rainfall during the monsoon season from mid June to September. The driest months were March and April with no precipitation and maximum temperature of 37.3^0C in April.

Selection of Study Sites

The study sites- Non-mortality Site (NMS) and Mortality Site (MS) lie in the Ghamandpur block of the range. Two *Shorea robusta* stands one containing many *Sal* trees with canopy dieback, mortality site and the other with healthy green, full crowns, non-mortality site were selected for the litter studies. 84% of the total area of the Ghamandpur block was under *Sal* mortality.

Table 1: Stand characteristics of the study sites

Stand character	Non-mortality site	Mortality site
Total no. of trees/hectare	926	759
Total no. of *Sal* trees/hectare	270	148
Total no. of *Sal* healthy trees/hectare	270	19
Total no. of *Sal* partially dead trees/hectare	-	48
Total no. of *Sal* dead trees/hectare	-	81
Average diameter of *Sal* (cm)	40.2	30.3

Methodology

Litter Collection

Litter studies were carried out in the non-mortality and mortality sites by laying down litter plots using the ground sampling methods of size 10m x 5m. All plant material and dead organic material debris was swept clean, weighed (litter fractions separately) and removed. Litter accumulating subsequently on the plots was collected each month on a fixed date for a period of one year. Litter was separated into different components (leaves, twigs, bark and fruits) and weighed in the field. Samples of each litter fraction were brought to the laboratory for oven dry weight estimation (at 80^0 C).

Forest Floor production

Biomass data on forest floor was collected from three (10 x 5) m^2 plots in the non-mortality site. The forest floor was distinguished into three layers i.e. L-layer: undecomposed litter (both leaves and twigs), F-layer: partially decomposed litter and H-layer: fully decomposed litter. Each layer was weighed separately for fresh weight in the field and samples brought to the laboratory for dry weight estimation.

Moisture Content

$$\text{\% Moisture Content (MC)} = \frac{\text{Fresh weight - Oven dry weight}}{\text{Oven dry weight}} \times 100$$

RESULTS AND DISCUSSION

Total Annual Litterfall of Sal

Annual litter production in the non-mortality site (NMS) was 5608 kg $ha^{-1}yr^{-1}$ and in mortality site (MS) it was 410 kg $ha^{-1}yr^{-1}$. On the basis of percentage, contribution of twigs to the total litter was the least (10%), seeds contributed 10.7% and leaves the maximum 79.3% as recorded in the non-mortality site. Mortality site had 97.6% of the total litter production as that of leaf litter (**Table 2).**

The amount of litter produced by the *Sal* trees in the non-mortality site was comparable to litterfall reported for *Sal* natural forests/ plantations (Indian Subcontinent) (Srivastava et al. 1972, Negi 1984, Pande 1986). The litterfall recorded in the mortality site was however remarkably reduced. Leaf-fall and twig-fall were in extremely low amounts in the site. Though it is known that litter production is dependent on stand density and age (litter production decreases with increasing age), it is worth noticing that in the present case the mortality site stand was younger (70 years) than the *Sal* stand in the non-mortality site (105 years). Comparatively the much reduced litter production by the stressed trees of the mortality site is due to the reduced canopy and subsequently reduced foliage biomass. The process of new leaf formation is hampered and the functional leaves are mainly seen adhering to the trunk of the tree. Fine woody litter production in the site was thus negligible. There was no seed production in the mortality site in the year of study. Suspension of seed production in stressed conditions by vascular plants is an energy conservation strategy. These plants respond to nutrient stress by reduced growth and reduced allocation to reproduction (Specht and Groves 1966, Grime 1979).

Table 2: Annual litter production in the NMS and MS on oven dry weight basis (kg $ha^{-1}yr^{-1}$)

Tree Species	Site	No. of trees/ha	Litter components			
			Leaves	Twigs	Fruits/Seeds	Total
S. robusta	NMS	270	4445	568	595	5608
	MS	67 (H+PD) 81(D)	400	10	Nil	410

*H= Healthy *Sal* trees; PD= Partially Dead *Sal* trees; D= Dead *Sal* trees

Leaf fall of Sal and its seasonality

Sal is a summer deciduous species, which seldom remains leafless. It shows a set pattern of leaf fall synchronizing with the climatic conditions prevailing in its natural zone. Leaf fall precedes the emergence of new foliage.

Leaf fall in the two sites differed considerably. In non-mortality site leaf fall amounted to 4445 kg $ha^{-1}yr^{-1}$ and in mortality site it was 400 kg $ha^{-1}yr^{-1}$. Peak period of leaf fall in the NMS was Feb–Mar with 50.7% of the total leaf fall. It was followed by Mar-Apr (24.5%) and Apr-May (13.7%). Rest of the year, leaf fall was either very poor or devoid of leaf litter and hence they did not differ among themselves significantly **(Table 3)**. Similar observation for *Sal* litter studies was also made by (Singh and Misra 1978, Negi 1984, Pande 1986).

In mortality site, it was delayed by a month and total leaf fall (98.5%) for the year was received in March-April and April-May. There was negligible leaf fall in the other months of the year **(Figure 1)**.

Twig Fall

Twig litter production was 568 kg $ha^{-1}yr^{-1}$ in NMS and mere 10 kg $ha^{-1}yr^{-1}$ in MS. Maximum twig fall in the NMS occurred during April to June, 67% of the total twig fall. In mortality site very little twig fall was observed in the month of April and May **(Table 3** and **Figure 1).**

Seed Production

In NMS, seed production was in the month of May–June (595 kg $ha^{-1}yr^{-1}$). However, no *Sal* seed production was observed during the year of study in MS.

Table 3: Monthly data of litter production (Oven dry weight expressed in kg $ha^{-1}yr^{-1}$)

Period	**NMS (kg $ha^{-1}yr^{-1}$)**					**MS (kg $ha^{-1}yr^{-1}$)**				
	Leaf	Twig	Fruit/ seed	Total	% of the total	Leaf	Twig	Fruit/ Seed	Total	% of the total
Nov–Dec	52	–	–	52	0.9	–	–	–	–	–
Dec–Jan	30	–	–	30	0.5	1	–	–	1	0.2
Jan–Feb	–	–	–	–	–	–	–	–	–	–
Feb–Mar	2255	52	–	2307	41.1	4	–	–	4	0.9
Mar–Apr	1091	22	–	1113	19.9	276	6	–	282	68.8
Apr–May	610	202	–	812	14.5	118	4	–	122	29.8
May–Jun	155	179	595	929	16.6	0.6	–	–	0.6	0.2
Jun–Jul	10	51	–	61	1.1	0.4	–	–	0.4	0.1
Jul–Aug	–	–	–	–	–	–	–	–	–	–
Aug–Sep	15	10	–	25	0.4	–	–	–	–	–
Sep–Oct	85	12	–	97	1.7	–	–	–	–	–
Oct–Nov	142	40	–	182	3.3	–	–	–	–	–
Total	**4445** (79.3%)	**568** (10.0%)	**595** (10.7%)	**5608**		**400** (97.6%)	**10** (2.4%)	**–**	**410**	

In both the sites *Sal* is behaving as drought deciduous with the major portion of leaf fall occurring during the summer months. Leaf fall in response to increase in temperature and low soil moisture is a process to check on the evapo-transpiration demands and is thus a water conservation process of the tree. It is observed that the remaining part of the year, non-mortality site had scanty leaf fall (24.7%) whereas in mortality site it was negligible to record. This strategy adopted by *Sal* to retain its leaves for longer duration is probably a nutrient conservation adaptation (Chapin 1991). As a consequence of the greater longevity and slower replacement of leaves in plants of stressful habitats, the rate of nutrient cycling between plant and soil is reduced (Monk 1966, Thomas and Grigal 1976).

Leaf formation in the mortality site was much restricted probably due to limitations of nutrients and water as the period of emergence of new leaves in the mortality site was marked by significantly low soil moisture status (**Figure 2**). Water uptake and the ability to access soil water during dry season, affects the physiological performance of leaf and the whole plant (Bucci et al. 2004).

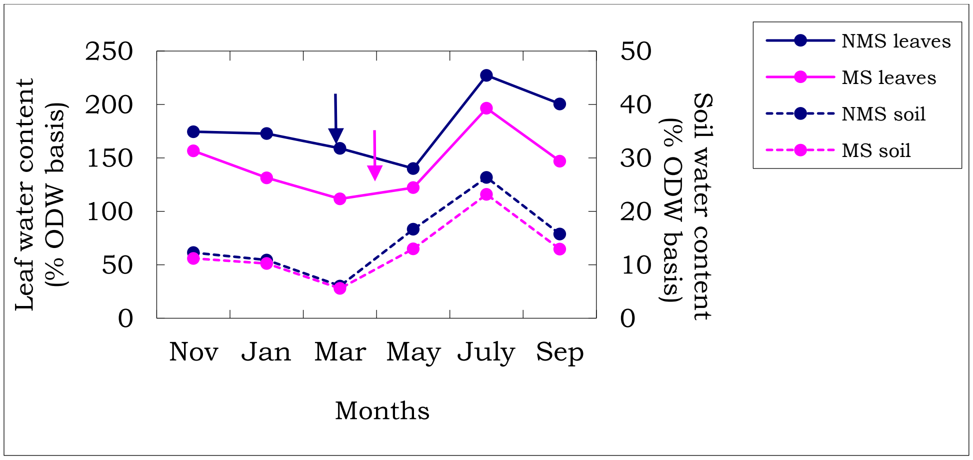

Figure 2: Seasonal variation in *Sal* leaf water content and the soil moisture content (% on ODW basis). (Arrow marks the production of new leaves)

FOREST FLOOR BIOMASS AND SURFACE SOIL

The results of studies conducted on forest floor and surface soil in the non-mortality site are shown in **Table 4.** 'H' layer contributed maximum (52.4%) to the total forest floor biomass followed by 'F' layer (31.2%) and 'L' layer (16.4%) respectively. Forest floor accumulation in the mortality site could not be assessed due to reduced litter over the year and also because the area was subjected to biotic interferences.

Table 4: Forest floor biomass in the non-mortality site and weight of the surface soil on oven dry weight basis.

Forest floor layers	Biomass (kg ha^{-1})
L	
Leaves	106
Twigs	108
F	408
H	686
Total	**1308**
Surface soil (0-30 cm)*	3840 (t ha^{-1})

* Both for NMS and MS

CONCLUSION

Litter production and the Forest floor of the study area was greatly influenced by disturbances and subsequent *Sal* mortality due to stressful conditions. The mortality site showed marked differences in temporal variability of litter production and in total litter fall of *Sal* throughout the study period compared to the non-mortality site. Greatly reduced litterfall in the mortality site had not only been the consequence of decreased density of healthy *Sal* trees in the area but also due to its highly reduced canopy and subsequent reduction in foliage biomass. Reduced growth, suspension of seed production, increased longevity of leaves, slower replacement of leaves and greater translocation of nutrients especially nitrogen and potassium was observed in the *Sal* trees of the mortality site. This observation is consistent with the general conclusion that plants of infertile habitats are adapted to conserve mineral nutrients rather than to maximize the rate of capture in response to stress. Anthropogenic disturbances in the forest corridor have predisposed *Sal* to adopt stress tolerant strategies. Conclusion from this case study can be further complemented for comprehensive understanding of the ecological processes in the stressed forest and subsequent management of tree mortality.

REFERENCES

- Berg, B. (2000) Litter decomposition and organic matter turnover in Northern forest soils. *For. Ecol. Manag.*, **133**: 13-22.
- Bucci, S.J., Goldstein, G., Meinzer, F.C., Scholz, F.G., Franco, A.C., Bustamante, M. (2004) Functional convergence in hydraulic architecture and water relations of tropical Savanna trees: from leaf to whole plant. *Tree Physiol.*, **24**: 891-899.
- Champion, H.G. and Seth, S.K. (1968) *A revised classification of the Forest Types in India.* Manager Publications, GOI, New Delhi.
- Chapin, F.S., III. (1991) Effects of multiple environmental stresses on nutrient availability and use. In Mooney, H.A., W.E. Winner and E.J. Pell, eds. *Response of Plants to Multiple stresses*. Academic Press: San Diego, pp. 67-68.
- Chauhan, P.S. (2001) Sal (*Shorea robusta* Gaertn.f.) Mosaic Characterization in Doon Valley. *D.Phil. Thesis*, Deemed University, Forest Research Institute, Dehradun, India.
- Fahrig, L. (2013) Rethinking patch size and isolation effects: The habitat amount hypothesis. *J. Biogeogr*. **40**, 1649-1663.
- Gautam, M. K., Tripathi, A. K., Manhas, R. K. (2008) Plant Diversity and Structure of Sub-Tropical *Shorea robusta* Gaertn. F. (Sal) Forests Of Doon Valley, India. *Indian Journal of Forestry*, **Vol. 31(1)**: 127-136.
- Grime, J.P. (1979) *Plant strategies and Vegetation Processes*. NY: Wiley, pp**.** 222.
- Kukreti, P. and Negi, J.D.S. (2004) Tree mortality and vegetational changes in a natural Sal forest of Barkot Range, Dehradun Forest Division. *Annals of Forestry*, **12**: 47-55.
- Monk, C.D. (1966) An ecological significance of evergreenness. *Ecology*, **47**: 504-5.
- Negi J.D.S., Shah, D., Kukreti, P., Negi, M., Basera, H.S., Kamboj, S.K. and Chauhan, P.S. (2002) An ecological assessment of Sal mortality in Uttaranchal. *Annals of Forestry*, **10 (2)**: 193-203.
- Negi, J.D.S. (1984) *Biological productivity and cycling of nutrients in managed and man made ecosystems*. D.Phil. Thesis, Garhwal Univ., Srinagar, India.
- Pande, P.K. (1986) *Litter production and decomposition, mineral release and biochemical diversity of four forest stands at F.R.I. demonstration area.* D.Phil. Thesis, Garhwal Univ., Srinagar, India.
- Pandey, R.R., Sharma, G., Tripathi, S.K. and Singh, A.K. (2006) Litterfall, litter decomposition and nutrient dynamics in a subtropical natural oak forest and managed plantation in northeastern India. *Forest Ecology and Management,* **240(1-3)**, 96-104.
- Singh, K.P. and Misra, R. (1978) Structure and functioning of natural, modified and silvicultural ecosystems of eastern Uttar Pradesh. *Technical Report*, Oct., 1975-1978.

UNESCO Programme on Man and Biosphere. B.H.U., Varanasi.

- Specht, R.L. and Groves, R.H. (1966) A comparison of the phosphorus nutrition of Australian heath plants and introduced economic plants. *Aust. J. Bot.*, **14**: 201-21.
- Srivastava, P.B.L., Kaul, O.N. and Mathur, H.N. (1972) Seasonal variation of nutrients in foliage and their return through leaf-litter in some plantation ecosystems. In *Proc. Symp. Man-made Forests in India*. Society of Indian Foresters, Dehra Dun, pp. 66-72.
- Thomas, W.A. and Grigal, D.F. (1976) Phosphorus conservation by evergreenness of mountain laurel. *Oikos*, **27**: 19-26.
- Visalakshi, N. (1993) Litterfall, standing crop of litter and their nutrients in two tropical dry evergreen forests in India. *International Journal of Ecology and Environmental Sciences*, **19(3)**, 163-180.
- Wang, Q., Wang, S., Huang, Y. (2008) Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China. *For. Ecol. Manag.*, **255**: 1210-1218.
- Waring, Bonnie G. (2012) Meta-analysis of Climatic and Chemical Controls on Leaf Litter Decay Rates in Tropical Forests. *Ecosystems*, **Vol. 15**, pp. 999-1009.
- Xuluc-Tolosa, F.J., Vester, H.F.M., Ramirez-Marcial, N., Castellanos Albores, J., Lawrence, D. (2003) Leaf litter decomposition of tree species in three successional phases of tropical dry secondary forest in Campeche, Mexico. *For. Ecol. Manag.*, **174:** 401-412.
- Yadav, R.S., Yadav, B.L., Chhipa, B.R. (2008) Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. *Agrofor. Syst.*, **73**: 1-12.

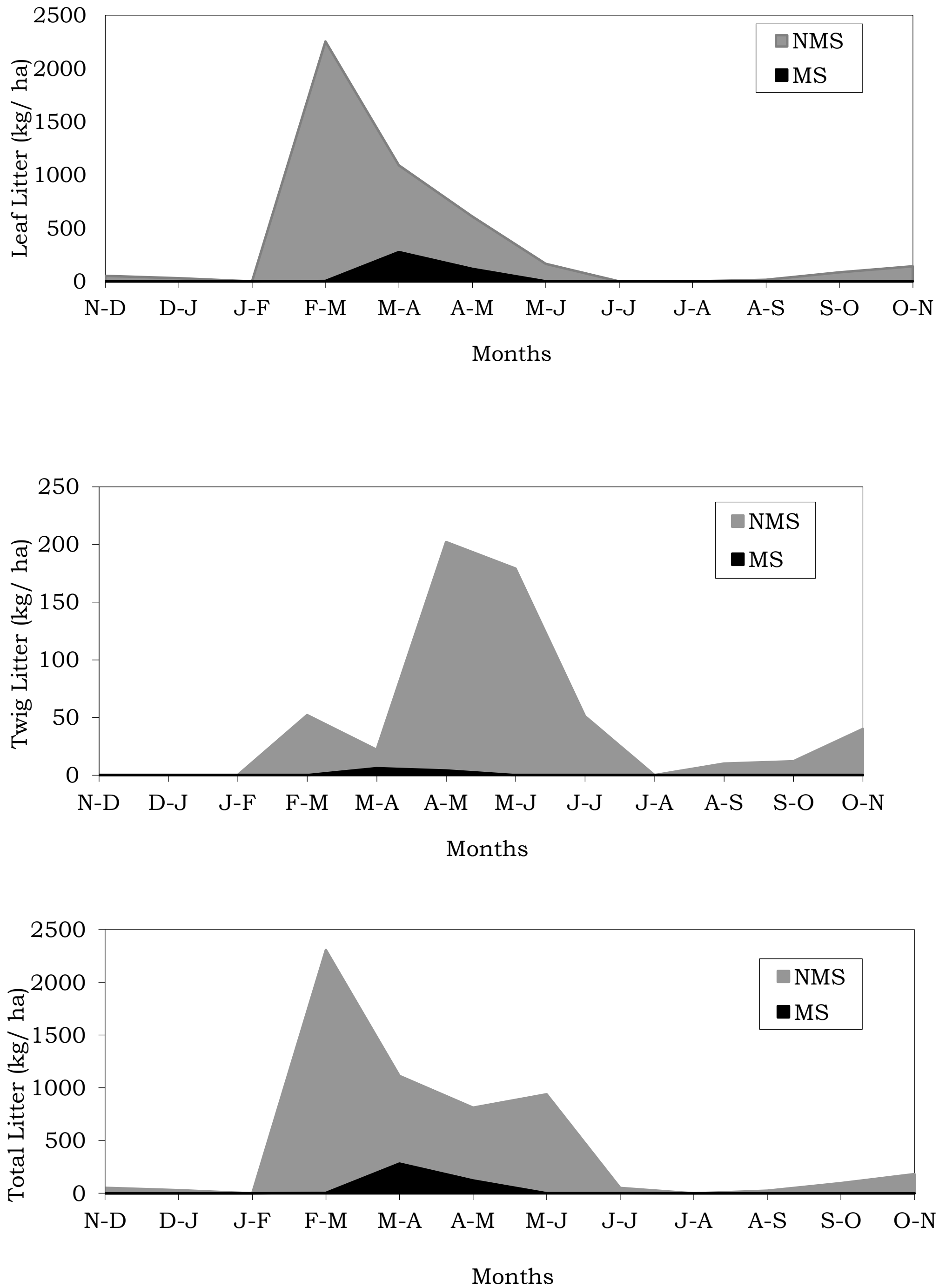

Figure 1: Seasonal variation in litter of Shorea robusta from non-mortality site and mortality site