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Investigating the rate of litterfall and decomposition in Phulai dominated forest of Pakistan: A nutrient cycling perspective

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Abstract

Phulai (*Acacia modesta*) is widely distributed and dominates in subtropical forests of Pakistan. Every year a huge amount of litter falls on the ground and decomposed to become part of nutrient cycling in this forest ecosystem. Although past research highlighted that llitterfall and roots decomposition is an important process in terrestrial C and N cycling. Unfortunately no attempt has been made in the past to explore the rate of decomposition of litter fall as well as the roots and subsequent entry into the soil as nutrients of this forest ecosystem. Therefore to cope with this knowledge gap one year data collection for total litterfall and decomposition bag experiment for leaf litter and roots of various classes (Fine having diameter <2mm, Medium = 2mm and coarse >2mm) was carried out. The study revealed that on average basis 31.95 t ha^{-1} yr^{-1} litterfall in this ecosystem with 32 % mass loss from decomposition. Moreover fine, medium and coarse roots deteriorate at rate of 33%, 34% and 29% of initial mass respectively. The examination of the supplements from litter fall as Nitrogen (N), Potassium (K), Phosphorus (P) and Carbon (C) entering into the soil at rate of 0.209, 1.31, 0.139 and 4.45 t ha^{-1} yr^{-1} respectively. Our results suggest that the decomposition rate and nutrient release in this forest ecosystem are closely linked to initial nutrients and C contents of litters. Thus, further investigations are required to explore specific content of the easily decomposable component in order to assess the effect these components on decomposition.

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Introduction

In forest biological system, decomposition plays out a basic part as it's far crucial for primary production in surroundings (Berg and Mc Claugherty, 2014). Decomposition is capable by mineralization of dead natural organisms through digestion system by utilizing microorganisms (Prescott and Grayston, 2013). Leaf litter decay is significantly influenced by physio-substance nature of the leaves of the species adopt (Berg and Mc Claugherty, 2010). Quality of litter depends on physical and chemical composition of litter (Melillo *et al.,* 1982). Decomposition of roots differs from leaf decay due to composition of litter (Wedin, 1999). They are unique in synthetic quality and composition as root litter has higher accumulation of refractory minerals, for example, suberin, polyphenols and lignin, than leaf litter (Wedin, 1995).

Litter decay is essential in the all-inclusive carbon circulation especially for soils having biggest sinks of carbon (Paruelo *et al.,* 1998). Likewise different supplements like NPK are imperative for a healthy plant development.

The collection of the dry biomass and entering of supplement into soil through litterfall and root deterioration are the crucial parts of supplement cycling in plant groups far and wide. This dry biomass comes back to soil by going through the procedure of the disintegration being affected by substrate and climatic conditions to produce soil supplements fundamental for plant development and also more carbon sequestration.

Phulai botanically called *Acacia modesta*, falls in sub-tropical thorn and sub-tropical dry evergreen forests of Pakistan extended in KPK, Punjab and Baluchistan provinces (Champion, 1965). It is deciduous, drought tolerant, frost-resistant and quickly developing species which display high rate of litterfall. It belongs to family *Fabaceae* (Baquar, 2010). Leaves, barks and different parts of this tree are utilized as pharmaceutical and firewood. It have diverse properties of mitigating, fringe pain relieving and additionally hostile to microbial (Jawla *et al.,* 2005). In numerous tropical ranges of Pakistan, *Acacia modesta* is vital in social and farm forestry. It is additionally essential for control of desertification by means of wind breaks and sand ridge adjustment. Acacia forests are huge valued sources of grain, fuel, tannins, small timber and nectar. The tree is uncommonly drought tolerant and survives on numerous tricky places (Alexander, 2013).

In present study we examined the measure of aggregate leaf litterfall in the phulai dominated forests and in addition the deterioration rate of the litter to evaluate the aggregate supplement contribution to soil in one year. It was hypothesized that progressively the rate of disintegration, more Nitrogen, Potassium, Phosphorus and Carbon will be stored into soil surface. The primary goals of the study were (1) the measure of leaf fall; (2) decomposition rate of leaf and root litter and (3) elemental composition of root and leaf litter of *Acacia modesta*.

Material and methods

Study site

The study region is naturally situated at 33° 32' 7" to 33° 40' 7" N and 72° 38' 26" to 72° 50' 37" E longitudes with average height of 354 m above sea level. The territory falls climatically in warm sub-tropical and sub-humid monsoon area. Two distinctive rainy seasons occur, one is Rabi (winter) with a crest in February-March furthermore the other is Khareef (summer) with a crest in July-August. Range of mean annual temperature varies from 5 ℃ to 30 ℃. The investigations on soil moisture (%) and soil temperature (°C) during the study year revealed that during monsoon season and moist winters, soil moisture was highest (26.15 %) while during dry winters and dry summers it was lowest (5.02 %) (Fig. 1).

The vegetation of the zone is ordinary of scrub forest. *Olea ferruginea* and *Acacia modesta* are the dominating species. *Dalbergia sissoo*, *Populus deltoides* and *Eucalyptus camaldulensis* also found in the site. *Acacia modesta* is the prevailing tree in the cropped site while elective tree species are discovered exclusively on hilly areas and foothills.

Dominating bushes includes *Dodonaea viscosa* and *Zizyphus nummularia* are dominating. The grass species comprise of *Cymbopogon citratus*, *Heteropogon contortus*, *Panicum antidotale* and *Cynodon dactylon*.

Sampling and data collection

Initial field work

In the start of the experiment, fallen leaves were collected under the phulai canopy. For collection of the roots, the soil was exhumed around the trees (n=3) within 1m radius. Roots were cut with the aid of cutter and axe. Afterward they were carried to laboratory where they were washed or cleaned with filtered water and dried in oven at 70 ℃ for 2 days. Later they were categorized according to their diameter in 3 classes as fine <2mm, medium 2mm and coarse >2mm.

Axciallary estimation

Moisture in soil was checked after every two months to measure the distinction because of climate variation. Soil temperature was calculated after at regular intervals with the assistance of thermometer under soil (at the depth) of 10 cm (Vogt *et al.,* 1995). To discover the distinction in mass loss of leaves and diverse classes of roots one way ANOVA was applied.

Litterfall collection

For litterfall collection, nylon net trappers (mesh size = 2mm) was installed 1m above ground with the help of PVC pipe below the tree canopy. After every two months litter was collected from the trapper and carried to the research centre. Leafy and non-leafy litter (including flower, legumes, twigs & branches) were isolated from each other, measured independently.

Decomposition bag and leaf litter decomposition

Litter bag technique was adopted to investigate the leaf litter decay. The size of litter bag was 15 cm × 20 cm (Le *et al*., 2003). Bags were prepared from nylon net of 2 mm mesh size. Leaves collected from field were cleaned or oven dried in laboratory. Later they were filled in the litter bags at a rate of 10 g per bag. Overall 30 bags were placed above the soil surface under tree canopy. After every 2 months 5 bags of leaf litter were brought to laboratory. Samples were extracted from bag, cleaned from debris, washed, oven dried and weighed for estimation of weight loss with the help of weighing balance (SATWICK-VIC006).

Root Litter decomposition

After root classification they were weighed and put in the decomposition bag. Different bag sizes were used for different root classes. This was decided after comprehensive review of literature. Fine roots of less than or equal to 2 mm diameter were filled in bags having 10 cm × 10 cm size and weight of fine roots in one bag was 5 g (Fuji and Tekada, 2012). Medium roots of 2 – 3 mm diameter were filled in bags having 10 cm × 15 cm size and weight of medium roots was 10 g in 1 bag (Olajayigbe *et al.,* 2012). Coarse roots of greater than 3 mm diameter were filled in bags having 30 cm × 30 cm size and weight was 100 g in 1 bag (White *et al.,* 1998). The mesh size was constant for all bags as 2 mm. Overall 30 bags of each class were filled with oven-dried roots and placed in the soil (10cm below ground) surface under tree canopy. After every two months 5 bags of each class were taken and carried to laboratory, extracted from bag, cleaned from debris or fungus and weighed for estimation of weight loss with the help of weighing balance (SATWICK-VIC006).

Root density and biomass

Roots taken from the zone (1m range radius along tree bole) around tree were firstly used to quantify root density (Gajri *et al.,* 1994). Roots lengths were measured with the assistance of measuring tape (Eastern –SMT 585C). All the roots after root density estimation were weighed for biomass (Blouin *et al.,* 2008).

Elemental composition

To investigate the nutrient status, leaf and root litter were crushed in an electric grinder (SPEX-5100). Leaf and root litter were replicated thrice a time to find the aggregate values of chemicals present in them. Generally, 0.5g of every specimen was distilled in 100ml jar by sulphuric acid overnight. At that point the specimens were processed at 358 ℃ through hot platters.

At 178 ° C few drops of hydrogen peroxide were included till sample turn colourless. Nitrogen, phosphorus and potassium were separated by dilution. Conventional Kjeldahl, auto analyser system and atomic absorption spectroscopy (Olsen *et al.*, 1963) were applied for nitrogen, phosphorus and potassium respectively. Ash method was used for carbon estimation.

Statistical analysis & calculations

The following equation (Beets *et al.,* 2008) was adopted to determine decomposition rate constant, k, from the decay curve:

$M_o / M_t = e^{-k* t}$

$Ln (M_o / M_t) = k \times t$

Here, M_o is the initial mass of litter, M_t is the mass of litter at removal time, t is the duration for decomposition (must be year or more) and k represents decay constant.

The decomposition percentage at different times was also determined by the following equation:

$R = (100 - 100 \times e^{-kt}) \times 100\%$

The relationship between soil moisture, soil temperature and decomposition rate was developed using regression techniques. Analysis of variance was carried out determine the significant difference in rate of decomposition of leaves and roots with the passage of time.

Results and discussion

Litterfall

It was revealed that the total amount of litter fall (including leaves, twigs and pods) in the Phulai dominated subtropical forest is 31.95 t ha^{-1} yr^{-1}. Annually the highest litterfall was in April to September (72–96%) while it was lowest (4-28%) between Octobers to March.

Table 1. Diameter, size of bags, weight per bag of different categories of leaf and root litter.

Sr. No.	Categories of Litter	Diameter (mm)	Size of Bags (cm)	Weight per bag (g)	Reference
1	Leaf	-	15 × 20	10	Lee *et al.,* 2003
2	Fine Root	≤ 2	10 × 10	5	Olajuyigbe *et al.,* 2012
3	Medium Root	2-3	10 × 15	10	
4	Coarse Root	≥3	30 × 30	100	

As *Phulai* is deciduous in nature, due to this reason it sheds highest litterfall in dry & warm) with mass (82% approx.) while reduced litter fall was in cold & wet seasons). The lowest amount of litterfall was noticed in the month of January. The total amount of litter fall including pods and twigs has been showed in (Table 2). Our results are consistent with Singh *et al., (*1999), who experimented in sub-tropical evergreen forests to find out the litter decay and percentage of nutrient release in different plants. They calculated 73% decay in *Acacia indica* with overall litterfall in 8-9 years old tree canopy as 12.69 Mg $ha^{-1}y^{-1}$. Our study showed litter high amount of litterfall due to little higher rainfall and dependency of litterfall on soil moisture, temperature, fertility and nutrient status which are directly related to the litter generation (Jorgensen *et al.,* 1995).

Leaf litter decay

Leaf litter bags were put on the ground for researching the rate of deterioration in-situ conditions. The initial weight of leave litter in one bag was 10 g and on 363rd day, the weight was 3.186 g due to decomposition. The aggregate mass loss (%) after one year of incubation was 39.14%.A linear relationship with R^2 =0.97 (Fig. 2) was found between leaf mass loss (%) and the number of days of decomposition (incubation).

Table 2. Amount of individual tree components and cumulative litterfall.

S. No.	Sampling days	Twigs (t)	Leaves (t)	Pods (t)	Cumulative litterfall (t ha^{-1})
1	56	2.54	3.29	1.58	7.41
2	122	3	2.98	2.143	8.123
3	179	2	0	0	2
4	243	3	0	0	3
5	300	2.16	1.12	0.666	3.946
6	363	2.23	3.661	1.58	7.471
Total	-	14.93	11.051	5.969	31.95

The value of decomposition constant "k "was calculated as 1.36 $\times 10^{-3}$ after 363 days. One way ANOVA was carried out to determine the variation in the decay rate of the leaf litter during different time of the year. It was revealed that there is significant variation ($P<0.001$) in decomposition rate during the different time period (Fig. 2).

Our study pointed out >61% decay rate and it is compatible with the Powers *et al.* (2009), who reported >95% deterioration of the sub-tropical species. However there is a need to investigate the effect of numerous elements, for example, arrangement of bags on under and above ground, litter quality, precipitation, insects, fungal attack and climatic variables affecting decomposition.

Table 3. Quantities of Nitrogen, Potassium, Phosphorus and Carbon (g kg^{-1}) present in the leaf and root litter of *Phulai.*

Tree Parts	Nitrogen (N)	Potassium (K)	Phosphorus (P)	Carbon (C)
Leaves	2.712 ± 0.677	15.46± 0.043	1.35 ± 0.016	49.73 ± 1.883
Twigs	2.583 ± 0.243	11.344± 0.045	1.303 ± 0.065	50.453± 1.333
Pods	1.275 ± 0.100	9.492 ± 0.089	1.712 ± 0.146	39.214 ± 2.010
Roots	2.553 ± 0.243	10.46 ± 0.126	1.186 ± 0.0280	37.25 ± 1.562
Total	9.123 ± 1.263	46.756 ± 0.303	5.551 ± 0.255	176.647 ± 6.788

Roots litter decomposition

a) Fine roots decomposition

The initial mass of fine root litter in one bag was 5 g and at 363rd day, the mass was weighed as 1.65 g after decomposition. Mass decay in one year was recorded as 46.78%. After 363 days value of decomposition constant "k" was calculated as 1.33×10^{-3}. The regression analysis revealed linear relationship (R^2 =0.96) between rate of mass loss (%) and time of incubation (Fig. 3). Also analysis of variance indicated significant difference in mass loss rate at different period of the year.

Makita and Fujii (2015) demonstrated that fine root litter decay and their weight reduction with passage of time followed an exponential function. This was due to microbe's respiratory rates related with the litter composition with various species (Fanin *et al.,* 2011). Moreover, studies pointed out that fine root decay had important role in carbon addition in soil through decomposition as diverse factors influence on decay of fine root litter for enhancing the carbon sequestration rate (Emily *et al.* 2013).

Medium root litter

The results indicated that the initial mass in one bag of medium root litter was 10 g and at 363rd day, the mass was weighed as 3.394 g after decomposition. Mass decay in one year was recorded as 39.70 %. After 363 days value of coefficient of decomposition "k" was 1.29×10^{-3}. Regression analysis revealed linear relationship was found between mass loss (%) and time of incubation (R^2 =0.83; Fig. 4).

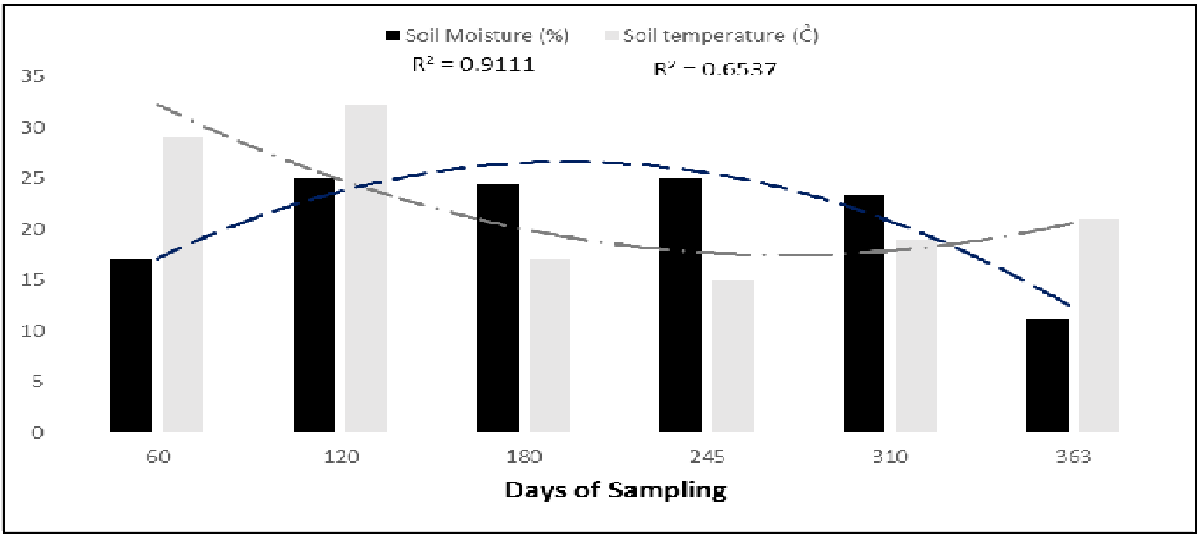

Fig. 1. Soil moisture (%) and Soil temperature (°C) in study area.

Our results are also consistent with Xin *et al.* (2012) who applied correlation analysis between medium roots decay and time in four unique species and discovered medium roots (=2mm) of every specie demonstrated exponential (R^2 =0.92) and essentially negative relationship. In contrast, the exponential condition of decomposition give a good match comparable to linear relation (Silver and Miya, 2001).

Coarse root litter

The investigations on decomposition of coarse roots revealed 41.4 % mass loss annually.

The value of the coefficient of decomposition "K" was 1.47×10^{-3}.A linear relationship was found between mass loss (%) and time of incubation (R^2 =0.97; Fig. 5).

Past studies pointed out that coarse root deteriorated at slower rate, this may be because of low supplement discharge in the soil (Fahey *et al.*, 1988) and are less attracted to insects or contagious scatterings. Fine roots deteriorated quickly when contrasted with coarse and medium roots and this may be because of highest supplement composition introduced in them (Camiré *et al.*, 1991).

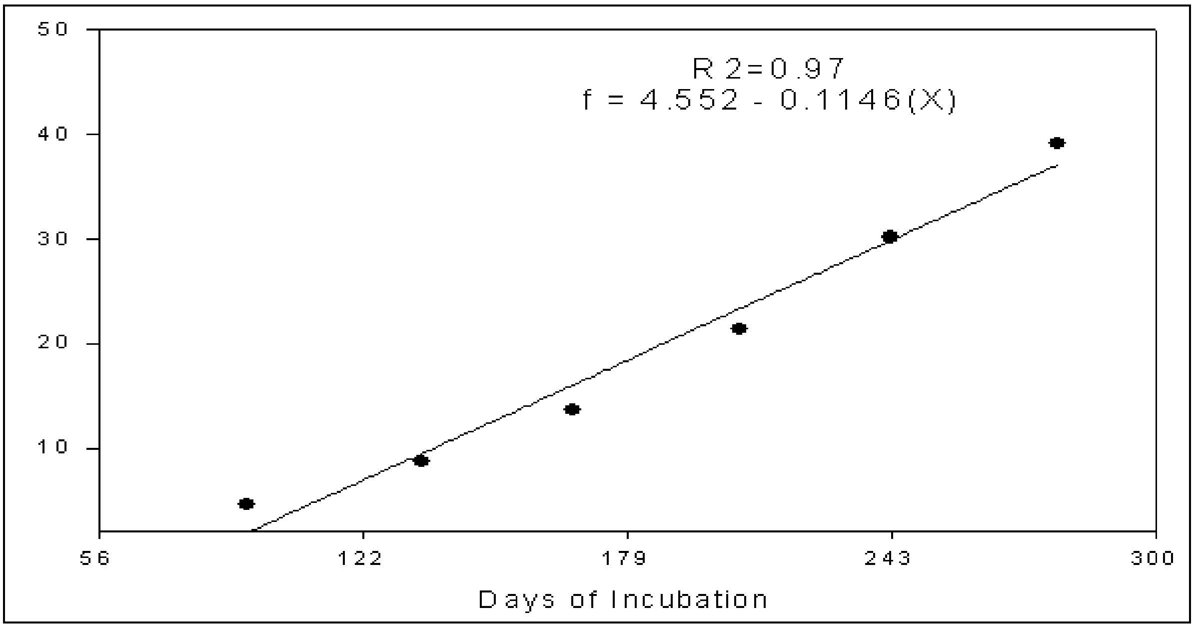

Fig. 2. Mass Loss (%) with days of incubation in Leaf litter.

In our study it was also observed that mass loss during summer seasons was quick while moderate during winter season. Deterioration rate R% is specifically identified with constant value K, higher rate of disintegration show high rate of K and vice versa. Current research relates with work of Alexander (2013) who worked on evaluation of *Acacia mangium* (9 year stand) decay for replenishment of degraded mined areas in Sunyani, Ghana. Decay constant value (k) was 0.005 to observe the continuous prospective mass loss in his study. He also observed rapidity of mass loss which was rapid in first 45 days (summer) while slower in the next days (winters). Reason of this decay speed difference was may be that decay rate is affected by environmental, topographic and climatic factors (Xiong *et al.,* 2008).

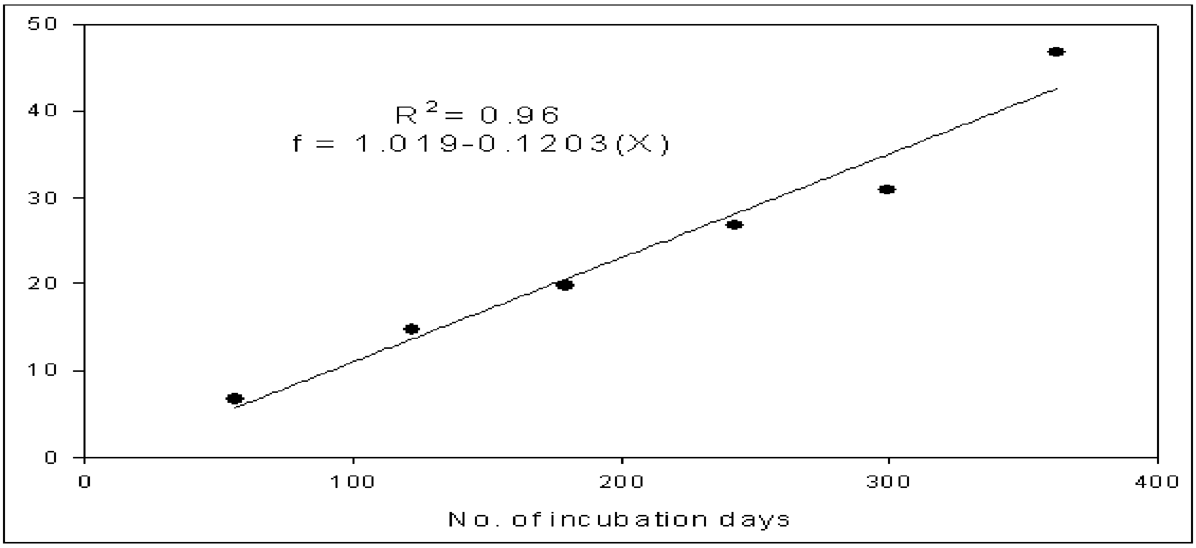

Fig. 3. Mass Loss (%) with days of incubation in fine root litter.

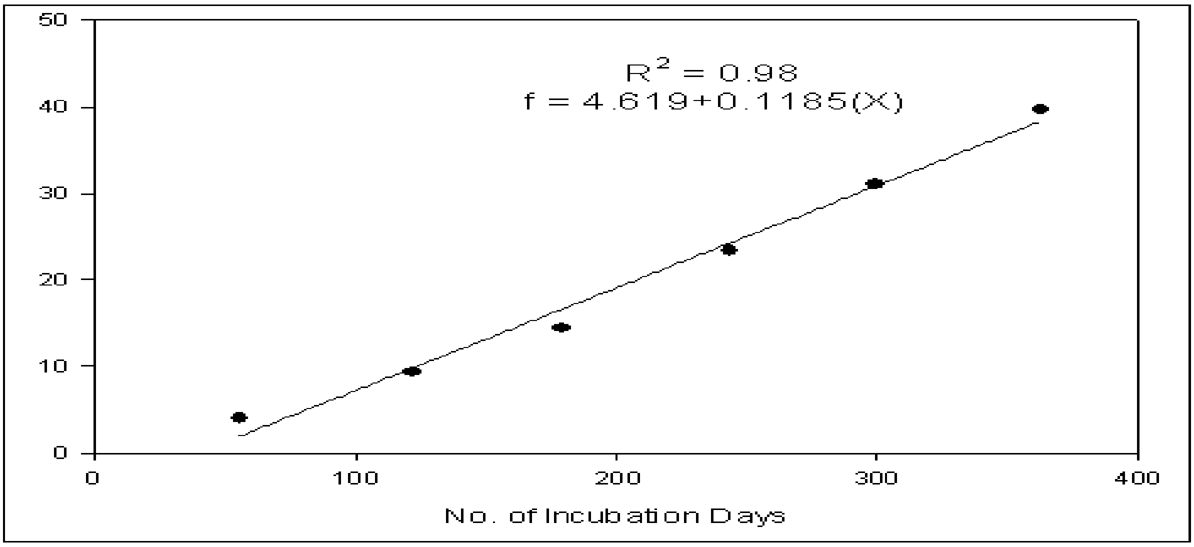

Fig. 4. Mass Loss (%) of medium roots during study period.

Nutrient input status

Study revealed that leaf litter contains approximately 50% (organic) carbon. Leaf decay enhances supplement components in soil deprived of affecting the substance assets of soil.

Nitrogen (N), potassium (K), phosphorus and carbon fixations were altogether higher in underground part (roots) of Phulai. The amount of N & K was highest in leaves while P was highest in pods/ legumes (Table 3).

A negative relationships amongst nitrogen and phosphorus concentration in litter at various durations of time and comparing % mass remaining (r = - 0.92 to - 0.97, P<0.001) The highest elemental composition in litter weight reduction as compared to initial elemental composition showed the trend for nitrogen and phosphorus fixation by fungus and insects (Singh *et al.*,1999).

Atkinson (1973) revealed that, nutrient status of the leaves is the best deciding component in the decay rate. Palm (1995) distinguished that elemental release way may be resolved from the compound structure of leaves. The rate of decay is specifically identified with the N and P concentrations and thus microbial movement is altogether subject to the nature of litter (Flanagan and Cleve, 1983).

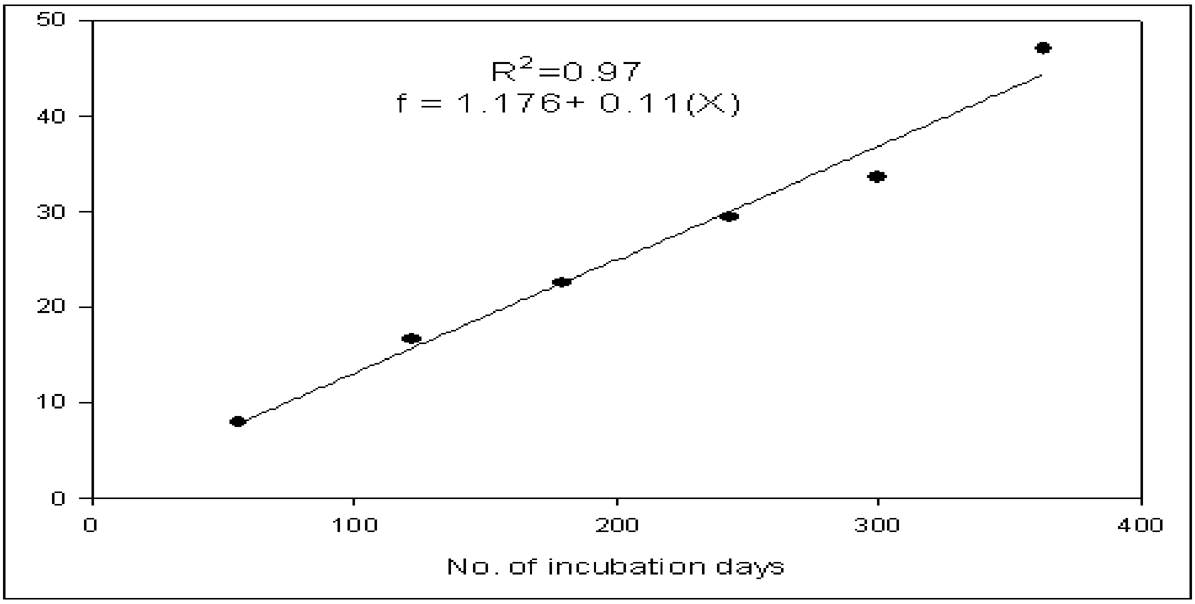

Fig. 5. Mass Loss (%) of Coarse roots during Study Period.

Organic carbon discharge is fundamental supplement for plant development and contributes to biochemical changes in the soil and control soil microbial action as well (Paul and Clark, 1989). Leaf litter for the most part contain low nitrogen, phosphorus concentrations and dissolvable sugars, because of translocation. Components like Potassium and Manganese are typically present in little amount and they are rapidly lost for microbial development and discharged as dissolvable particles in the soil (Waring and Schlesinger, 1985).

Conclusion

The investigations on total amount of litter fall (t ha^{-1} yr^{-1}) and decomposition rate of the leaf litter and roots of different diameter classes were investigated. It was concluded that on average basis 31.95 t ha^{-1} litter falls every year in phulai dominated sub-tropical forests of Pakistan with 32 % loss from decomposition.

Moreover, the rate of decomposition is higher in fine & medium roots as compared to coarse roots in this ecosystem. The examination of the nutrient input from above ground litter fall showed that Nitrogen (N), Potassium (K), Phosphorus (P) and Carbon (C) are entering in to the soil at a rate of 0.209, 1.31, 0.139 and 4.45 t ha^{-1} yr^{-1} respectively. This study provides basic information about the litterfall, decomposition rate and rate of nutrient inputs in phulai dominated forest. However further investigations are required to explore specific content of the easily decomposable component in order to assess the effect these components on decomposition.

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