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Leaf litter decomposition and nutrient release in *Salix* spp under temperate conditions of Kashmir valley (India)

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Abstract Litter bag experiment was carried out during 2006 - 2007 to study the role of microorganisms in leaf litter decomposition of *Salix alba* and *Salix fragilis* under natural *Salix* stands. The experiment was laid in completely randomized design with three replications which comprised ten treatment combination of 5 inoculants (No-inoculant, *Azotobacter chroococcum, Pseudomonas fluorescene*, effective microorganism and combination of *Azotobacter chroococum* + *Pseudomonas fluorescens* + effective microorganisms). Higher rate of decomposition of leaf litter was recorded in June in case of *Salix fragilis* (88.90%) as compared to *Salix alba* (80.16%). Lower rates of decomposition of both the species were recorded in January. Plant N, P, K, Ca, Mg and organic carbon release showed an increasing trend from July onwards upto November and immobilization of above nutrients was observed in December and January. In the succeeding months an increasing trend in the nutrient release was observed. Highest nutrient release was recorded under combined inoculation of *Azotobacter chroococcum* + *Pseudomonas fluorescens* + effective microorganisms followed by effective microorganisms as compared to other treatments and control. Combined inoculation resulted in a significant increase in total viable bacteria, fungi and actinomycetes followed by effective microorganisms, *Pseudomonas fluorescens*, *Azotobacter chrococcum* and control respectively. Thus the treatment combination of *Azotobacter chroococcum* + *Psuedomonas florescens* + effective microorganisms proved to be the best for decomposition of *Salix* leaf litter and nutrient release

Key words

Azotobacter chroococcum, Decomposition, effective microorganisms, Microbial inoculation, *Salix alba, Salix fragilis, Pseudomonas fluorescens*

Salix alba and *Salix fragilis* are considered as one of the most important tree species in temperate agroforestry systems. In India these species are extensively cultivated in western Himalayas upto 2400 m, mostly in Kashmir and Kullu valleys along river streams, canal banks and around lakes. These are fast growing multipurpose tree species and of late, these species have assumed a lot of importance in extensive planting programme both in homesteads and as avenue. These two species viz., *Salix alba* and *Salix fragilis* are deciduous in nature and attain a height of 20-25 m and 15 m respectively (Das, 1958). The light wood of *Salix alba* is commercially used in the cricket bat industry for the manufacture of cricket bats (Luna, 1995). Since these two species of Kashmir willow have multipurpose uses like cricket bat production, fodder value, fuel wood, small timber for rural house construction, packing cases for fruits like apple and as shelter belts and windbreaks for protection of agricultural and horticultural crops, large number of willows are planted every year. The trees being deciduous in nature are a source of substantial quantity of organic matter by way of litter fall. Litter production, decomposition and nutrient return in natural forests as well as in plantations are very important aspects of nutrient cycling, since a considerable amount of nutrients are returned through litter fall in the form of leaves, twigs branches, flowers and are available for reabsorption. The sequential process of litter fall, its decomposition and subsequent mineralization are essential in sustaining a dynamic forest ecosystem (Maguire, 1994).

Keeping in view the litter production, its possible contribution towards soil fertility and no work having been done on willow leaf litter decomposition, the present investigation were under taken to determine role of microbial inoculation on rate of decomposition and nutrient release from *Salix alba* and *Salix fragilis* leaf litter.

Materials and Methods

The present investigation were undertaken at the Forestry nursery of Department of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during 2006-07. Microbial inoculants, isolated from local forest stands, were used in the studies.

Litter decomposition studies

Litter bag techniques were used for leaf litter decomposition and nutrient release studies. Fresh leaves collected from local *Salix* stands were air dried for 24 hours. For microbial inoculation, thirty grams of leaf samples of both the species were filled in 120 nylon net bags of size 20 x 10 cm of mesh 2 x 2 mm and placed randomly under natural *Salix* stands. A thin layer of soil of 2 cm thickness was spread on the bags to avoid misplacement. Litter bags, collected at different monthly intervals from the plots treatment wise were first carefully removed the accumulated soil and other foreign material. After removing all the extraneous matter, the samples were washed in running water and finally in distilled water. The contents were dried, weighed and powdered for chemical analysis.

Chemical analysis of the samples

The fine powder of the residues sampled periodically was used for the estimation of nitrogen, phosphorous, potassium, calcium, magnesium and organic carbon as per standard procedures.

Microbial inoculation

For inoculation the different both cultures of microbial inoculants were applied to the leaf litter bags without disturbing the leaf litter bags.

Average weight loss

Average weight loss of leaf litter from litter bags was calculated by subtracting the final mass of dry matter after oven drying from original (initial) mass of dry matter at monthly intervals.

Microbial characteristics

One gram of sample from each treatment including control of both the species at monthly intervals upto 12 months was suspended in 10 ml of sterilized distilled water and serial dilutions of the suspension were prepared by further dilutions. Total viable populations of bacteria, fungi and actinomycetes were determined as per the standard procedures.

Results and Discussions

Average weight loss (g) during the decomposition of leaf litter of *Salix alba* and *Salix fragilis.*

During the present investigation, it was observed that microbial inoculants enhance the rate of average weight loss of leaf litter from litterbags significantly than the control (Tables 1, 2). However, the combined microbial inoculation resulted in maximum average weight loss of leaf litter over all the individual inoculants. Further, maximum weight loss was observed in June under combined microbial inoculation. While as minimum weight loss of leaf litter was reported in January in the absence of microbial inoculation. The faster rate of weight loss in June could be attributed to more penetration of solar radiation and subsequent temperature rise which might have boosted microbial activities (Swift *et al.*, 1979). Slow rate of decomposition in January could be ascribed to the low temperature which may also have resulted into low activity of decomposers (Pandey and Singh, 1982; Bahuguna *et al.*, 1990; Maithani *et al.*, 1996).

In general, it was observed that rate of decomposition in case of *Salix alba* leaf litter was slower than rate of decomposition of *Salix fragilis* leaf litter. The slow rate of decomposition of *Salix alba* leaf litter could be attributed to dominance of lignin, which protects the cellulose and other cell wall constituents from degradation (Chesson, 1997) and thus is more resistant to decomposition. Further, it might be due to the lower initial nitrogen content in leaf litter of *Salix alba* species. There are many other workers who had observed that species having lower initial nitrogen content decompose much slower than those with high initial nitrogen content (Broadfoot and Pieree, 1938; Anderson, 1973).

Nutrient release during decomposition

The observations on the nutrient release from leaf litter of both the species during decomposition are depicted in various figures.

Nitrogen release during decomposition

The mixed microbial inoculation resulted in maximum nitrogen release (Fig. 1) in June from litterbags and proved superior over mono-inoculants. It was followed by individual inoculation of *Azotobacter chroococcum*, effective microorganisms and *Pseudomonas fluorescens*. But, nitrogen release from litterbags depicted, in general, a decreasing trend in winter months of December and January. The initial increase in available nitrogen concentration of decomposing litter may be ascribed to the conversion of carbon into CO_2 due to faster oxidation and leaching of soluble carbon compounds (Kumar and Deepu, 1992; Kumar *et al.*, 2001). The decrease in nitrogen concentration in the later period can be attributed to higher demand for nitrogen during the intense microbial activity. The higher nitrogen release from litterbags in June, due to application of inoculations, lies in the fact that they enrich the litterbags with nitrogen through atmospheric nitrogen fixation and develop more microbial colonies inside the litterbags which therefore degrade the litter material more quickly and hence improve the soil environment (Singh *et al.*, 1998). Our findings are in agreement with the

results of Kumar and Deepu (1992), who also observed an increase in N release but a decrease in absolute amount of nitrogen in leaf litter of *Casuarina, Acacia* and *Leucaena*. Further, the decrease in nitrogen release in January may be due to the adverse climatic conditions and rapid immobilistion of N by microorganisms. Moreover, the leaching of water soluble nitrogenous substances might have accounted for its decrease (Nykvist, 1963; Kumar *et al.*, 2001).

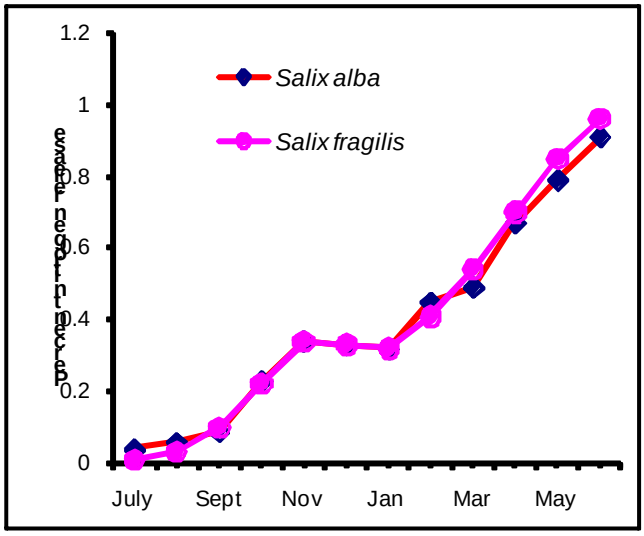

Fig. 1.Nitrogen release in leaf litter of *Salix alba* and *Salix fragilis* during decomposition

Phosphorus release during decomposition

The release of phosphorous (Fig 2) into available pool increased within all the treatments except control. Phosphorous release was more in the inoculated leaf litter when compared to control. The phosphorous release into the available pool was maximum (0.22 %) in June. Minimum release was observed in January (0.05%). The combined inoculation showed the best results, followed by Pseudomonas fluorescence, effective micro-organisms, Azotobacter chroococcum and control. The initial decrease in phosphorous release from leaf litter bags could be attributed to the better retention of P due to its immobile nature and the subsequent increase in P during the later half of study could be due to the rapid loss of P bounded in easily leachable compounds (Upadhyah, 1987).

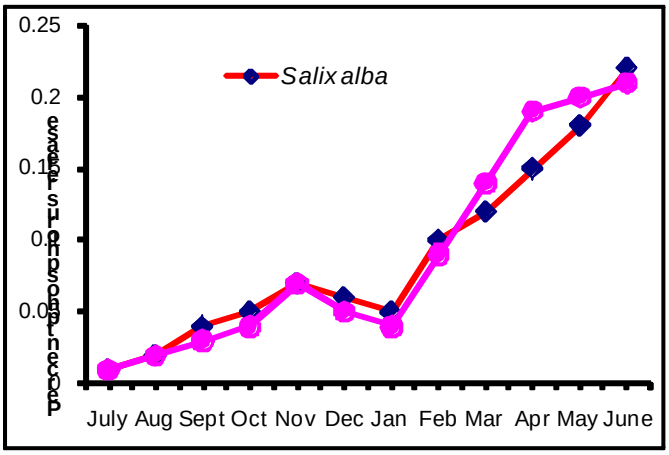

Fig. 2.Phosphorus release in leaf litter of *Salix alba* and *Salix fragilis* during decomposition

Potassium release during decomposition

The potassium release into the available pool increased gradually from July onwards to November, followed by decrease upto January (Fig 3). However, from February to June a sharp increase was noticed. Maximum potassium release was recorded in June and

minimum in January. The combined microbial inoculation resulted in maximum potassium release in June from leaf litter bags and proved superior over individual inoculants. The increase in K release from leaf litter bags in June could be attributed to high rainfall coupled with high humidity, temperature and microbial activity (Kunhamu, 1994). However, a decline in K release from leaf litter bags in winter months may be ascribed to lower rate of decomposition of leaf litter and immobilization of K by microbes (Nykvist, 1963).

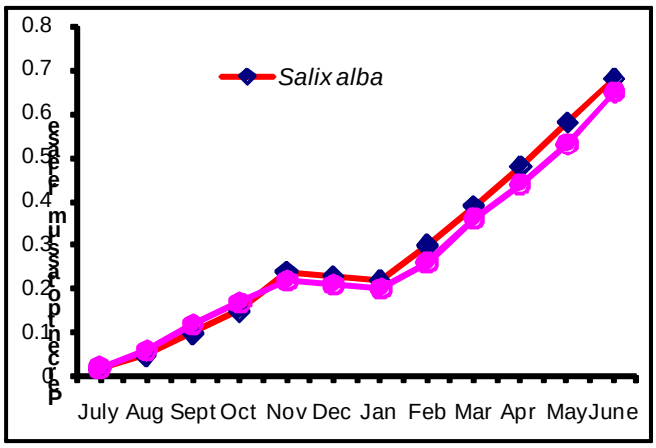

Fig. 3.Potassium release in leaf litter of *Salix alba* and *Salix fragilis* during decomposition

Exchangeable calcium release during decomposition

Exchangeable calcium release from leaf litter bags increased significantly from July to November, where it dropped upto January and again an increasing trend in release was noticed from February onwards to June (Fig. 4). Maximum release was noticed in June and minimum in January. Among the microbial inoculations, the combined inoculations showed the best results. The maximum release of Ca from leaf litter bags in June could be attributed to rapid rate of decomposition of leaf litter which is responsible for majority of Ca-release to the ecosystem (Gosz *et al* 1973). The decrease in Ca-release in January may be ascribed to lower rate of decomposition due to low temperature conditions and immobilization of Ca by microorganisms. Our results are in conformity with the results of Thomas (1969), who also showed similar results.

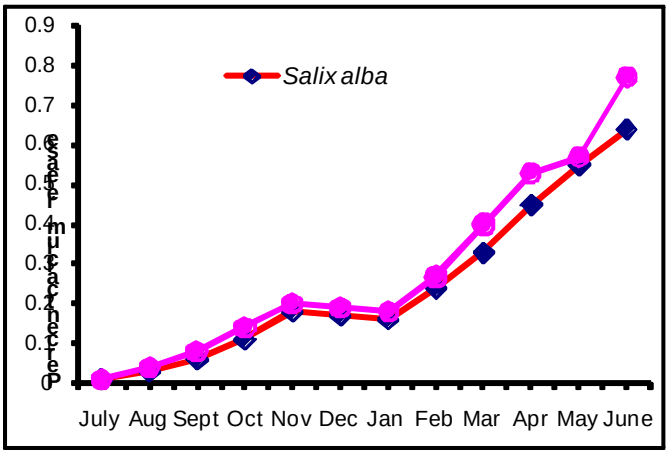

Fig. 4. Calcium release in leaf litter of *Salix alba* and *Salix fragilis* during decomposition

Exchangeable magnesium release during decomposition

Significant and maximum Mg-release (Fig 5) was recorded in June under combined microbial inoculations which was superior over mono-inoculants. It was followed by mono-inoculation of *effective micro-organisms*, *Pseudomonas fluorescens* and *Azotobacter chroococcum*. But Mg release from leaf litter bags showed a heavy decrease in the winter months. The increase in Mg-release from leaf litter

bags in June can be attributed to rapid leaching lossess which is triggered by higher rate of mineralization of this element held up in the leaf litter. Our results are in agreement with the findings of Sivakumar (1992), who made the similar observations. Moreover, the significant decrease in Mg release from leaf litter bags in January may be due to biological immobilization of Mg, which is also suggested as a mechanism of Mg retention in the initial stages of scot pine leaf litter decomposition (Staff and Berg, 1982).

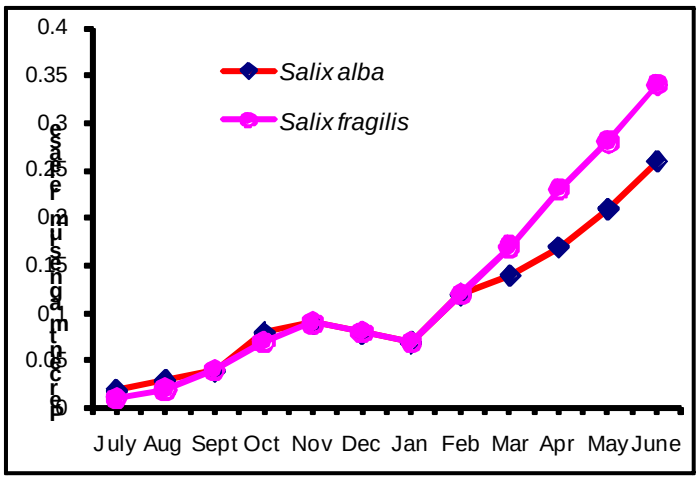

Fig. 5. Magnesium release in leaf litter of *Salix alba* and *Salix fragilis* during decomposition

Organic carbon content during decomposition

Organic carbon content in litter of *Salix alba* and *Salix fragilis* was reported significantly higher in the initial stages of the experiment (Table 3, 4). However, lower organic carbon content was revealed in the last month of the study period. Maximum content of organic carbon was reported under no-inoculation (control). Among the microbial inoculants, *Azotobacter chroococcum* proved best over mono-inoculants. It was followed by *Pseudomonas fluorescens* and effective microorganisms. The initial increase in organic carbon content could be attributed to slower rate of decomposition by microorganisms. However, the decrease in organic carbon concentration in the last month of the study period might be due to faster degradation of organic carbon as a result of enhanced microbial activity (Flaig, 1984).

Microbial population in leaf litter of *Salix alba* and *Salix fragilis*

Total viable bacteria

The present study revealed that total viable bacteria in leaf litter of *Salix alba* and *Salix fragilis* (Table 5, 6) got enhanced significantly over control with the application of microbial inoculants. A significant increase in viable count of bacteria was observed in June. The minimum bacterial count, however, was recorded in January. Effective microorganisms proved superior over *Pseudomonas fluorescens* and *Azotobacter chroococum*. However, the mixed inoculation resulted in maximum increase in viable count of bacteria over all the individual inoculants. The increase may be attributed to the production of growth promoting substances by microbial inoculants (Jackobsen *et al.*, 1994). The increase in bacterial population may also be due to the presence of suitable soil moisture and temperature conditions. However, the decrease in bacterial population in January may be ascribed to unfavourable climatic conditions (Vander, 1963).

Total viable fungi

All microbial inoculants had significant influence on total viable fungi (Table 7, 8) in leaf litter of *Salix alba* and *Salix fragilis*. The mixed inoculation gave highest viable count of fungi followed by *effective microorganisms*, *Pseudomonas fluorescens* and *Azotobacter chroococcum*. Total viable fungal count was recorded significantly higher in April. However, the fungal count showed a decreasing trend from April onwards till June. Minimum fungal population in leaf litter of *Salix alba* was revealed in January. The increase in fungal count in April could be attributed to the production of growth promoting substances secreted by soil microbes (Tien *et al.*, 1979). Further, the increase in fungal population may be due to the presence of suitable soil moisture and temperature conditions. The heavy decline in fungal count from April till June may be due to the fluctuations in climatic conditions. Moreover, the unfavorable climatic conditions in January might have accounted for its decrease (Vander, 1963).

Total viable actinomycetes

It was observed that all the microbial inoculants increased the total viable actinomycetes in

leaf litter of *Salix alba* and *Salix fragilis* (Table 9, 10) whether applied individually or in combination as compared to the control. Effective microorganisms proved superior among all individual inoculants followed by *Pseudomonas fluorescens* and *Azotobacter chroococcum*. However, mixed inoculation resulted in maximum increase in viable count of actinomycetes over individual inoculants. A significant increase in viable count of actinomycetes was observed in June. The minimum actinomycete count was however, depicted in January. The increase in actinomycete count in June may be due to more readily available nutrients and reduced competition among decomposer communities for food. (Alexander, 1977). Moreover, the increase in actinomycete population can also be attributed to the production of growth promoting substances secreted by soil microbes (Tien *et al.*, 1979) and presence of suitable climatic conditions. However, the decrease in actinomycete population in January may be ascribed to unfavorable climatic conditions (Vander, 1963).

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Table 1

Average weight loss (g) during the decomposition of leaf litter of *Salix alba*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	0.20	0.51	1.59	1.68	1.98	1.28	0.72	5.47	6.95	7.99	9.86	11.76	**4.17**
AZ	0.44	1.39	3.77	4.08	5.03	4.03	3.03	10.27	12.68	14.79	16.85	18.48	**7.90**
PS	1.34	2.28	5.17	6.03	6.97	5.97	4.97	12.00	14.07	16.28	18.08	20.68	**9.49**
EM	1.94	3.19	6.03	7.01	7.28	5.97	5.28	13.48	16.68	18.69	20.79	22.97	**10.77**
AZ+PS+ EM	2.36	4.29	7.22	8.11	8.87	7.87	6.87	14.99	18.00	20.48	22.02	24.05	**12.09**
Means	**1.25**	**2.33**	**4.75**	**5.38**	**6.02**	**5.02**	**5.01**	**11.24**	**13.67**	**15.64**	**17.52**	**19.57**	**-**

CD (0.05)

Treatment = 0.08 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.12 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 0.28 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 2

Average weight loss (g) during the decomposition of leaf litter of *Salix fragilis*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	0.16	0.50	1.80	1.90	3.00	2.00	1.60	6.89	7.95	8.97	11.48	13.47	**4.73**
AZ	0.81	1.80	4.00	4.80	3.13	4.10	3.91	6.69	7.95	8.97	11.48	13.47	**5.92**
PS	1.1.0	2.98	3.40	6.20	7.50	6.50	5.49	12.97	15.29	17.28	20.08	21.89	**10.06**
EM	2.24	4.00	6.23	7.90	7.90	7.30	6.99	14.69	17.66	20.00	21.79	24.87	**11.80**
AZ+PS+ EM	2.43	4.90	7.93	8.93	9.97	8.97	7.89	15.97	18.99	21.75	23.68	26.69	**13.17**
Means	**1.35**	**2.83**	**4.67**	**5.94**	**6.30**	**5.77**	**5.69**	**11.44**	**12.97**	**15.39**	**17.70**	**20.08**	**-**

CD (0.05)

Treatment = 0.04 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.07 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 0.16 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 3

Organic carbon (%) during the decomposition of leaf litter of *Salix alba*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	0.91	0.88	0.83	0.78	0.73	0.70	0.71	0.67	0.63	0.57	0.52	0.48	**0.70**
AZ	0.89	0.86	0.82	0.77	0.72	0.68	0.69	0.65	0.60	0.55	0.49	0.45	**0.68**
PS	0.90	0.87	0.82	0.77	0.72	0.69	0.70	0.64	0.58	0.53	0.47	0.43	**0.67**
EM	0.89	0.86	0.81	0.76	0.71	0.68	0.69	0.62	0.56	0.49	0.42	0.37	**0.65**
AZ+PS+ EM	0.88	0.85	0.80	0.75	0.70	0.67	0.68	0.62	0.55	0.49	0.41	0.35	**0.64**
Means	**0.89**	**0.86**	**0.81**	**0.76**	**0.71**	**0.68**	**0.69**	**0.64**	**0.58**	**0.52**	**0.46**	**0.41**	**-**

CD (0.05)

Treatment = 0.007 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.01 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 0.02 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 4

Organic carbon (%) during the decomposition of leaf litter of *Salix fragilis*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	0.93	0.90	0.85	0.79	0.73	0.70	0.71	0.66	0.60	0.54	0.48	0.41	**0.69**
AZ	0.93	0.88	0.82	0.75	0.69	0.66	0.67	0.54	0.48	0.40	0.33	0.36	**0.64**
PS	0.92	0.87	0.81	0.75	0.69	0.67	0.68	0.60	0.53	0.46	0.39	0.33	**0.63**
EM	0.67	0.86	0.78	0.70	0.64	0.61	0.62	0.53	0.46	0.37	0.30	0.27	**0.62**
AZ+PS+ EM	0.65	0.84	0.81	0.75	0.69	0.66	0.67	0.60	0.52	0.43	0.35	0.28	**0.56**
Means	**0.87**	**0.85**	**0.81**	**0.74**	**0.78**	**0.66**	**0.67**	**0.58**	**0.51**	**0.44**	**0.37**	**0.33**	**-**

CD (0.05)

Treatment = 0.02 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.04 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 0.08 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 5

Population of total viable bacteria (x 10^6 g^{-1}) during the decomposition of leaf litter of *Salix alba*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	8.00	11.00	13.00	14.00	15.00	13.00	8.00	10.00	16.00	18.00	21.00	25.00	**15.25**
AZ	1.00	13.00	15.00	17.00	19.00	17.00	10.00	12.00	22.00	25.00	27.00	30.00	**19.33**
PS	11.00	14.00	17.00	20.00	22.00	19.00	11.00	13.00	26.00	29.00	32.00	36.00	**22.50**
EM	13.00	16.00	19.00	22.00	23.00	21.00	12.00	14.00	28.00	32.00	36.00	40.00	**24.66**
AZ+PS+ EM	16.00	20.00	23.00	25.00	26.00	23.00	14.00	17.00	30.00	33.00	37.00	42.00	**27.41**
Means	**12.20**	**14.80**	**17.40**	**19.60**	**21.00**	**16.20**	**11.20**	**13.40**	**24.40**	**27.40**	**30.60**	**34.60**	**-**

CD (0.05)

Treatment = 0.46 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.72 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 1.61 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 6

Population of total viable bacteria (x 10^6 g^{-1}) during the decomposition of leaf litter of *Salix fragilis*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	10.00	12.00	12.00	15.00	16.00	14.00	10.00	13.00	17.00	19.00	24.00	27.00	**16.41**
AZ	11.00	14.00	17.00	19.00	20.00	17.00	11.00	14.00	23.00	26.00	29.00	32.00	**20.58**
PS	11.00	16.00	19.00	21.00	23.00	19.00	10.00	16.00	28.00	30.00	36.00	37.00	**24.02**
EM	15.00	18.00	21.00	24.00	25.00	21.00	13.00	18.00	30.00	34.00	38.00	42.00	**26.66**
AZ+PS+ EM	17.00	21.00	24.00	26.00	27.00	23.00	15.00	20.00	33.00	36.00	40.00	44.00	**29.08**
Means	**12.80**	**16.20**	**19.00**	**21.00**	**22.20**	**18.20**	**11.80**	**16.30**	**26.20**	**29.00**	**33.46**	**36.40**	**-**

CD (0.05)

Treatment = 0.41 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.94 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 2.12 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 7

Population of total viable fungi (x 10^3 g^{-1}) during the decomposition of leaf litter of *Salix alba*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	22.00	23.00	26.00	28.00	29.00	24.00	21.00	22.00	33.00	35.00	34.00	32.00	**28.83**
AZ	23.00	25.00	27.00	30.00	32.00	27.00	23.00	25.00	37.00	39.00	37.00	35.00	**31.58**
PS	26.00	27.00	29.00	31.00	33.00	29.00	25.00	27.00	41.00	43.00	41.00	38.00	**33.77**
EM	27.00	30.00	34.00	37.00	40.00	31.00	27.00	29.00	46.00	48.00	46.00	44.00	**39.25**
AZ+PS+ EM	29.00	32.00	35.00	38.00	40.00	33.00	28.00	31.00	47.00	52.00	49.00	46.00	**40.66**
Means	**25.40**	**27.40**	**30.20**	**32.80**	**34.80**	**26.60**	**24.20**	**27.80**	**40.80**	**43.40**	**41.40**	**38.66**	**-**

CD (0.05)

Treatment = 0.56 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.88 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 1.97 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 8

Population of total viable fungi (x 10^3 g^{-1}) during the decomposition of leaf litter of *Salix fragilis*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	23.00	23.00	25.00	28.00	29.00	26.00	22.00	24.00	33.00	37.00	36.00	34.00	**29.41**
AZ	25.00	27.00	27.00	31.00	32.00	28.00	24.00	27.00	38.00	40.00	38.00	37.00	**32.58**
PS	27.00	29.00	30.00	33.00	35.00	30.00	26.00	30.00	42.00	44.00	42.00	41.00	**35.58**
EM	31.00	33.00	36.00	39.00	42.00	32.00	29.00	32.00	48.50	50.00	47.00	45.00	**41.47**
AZ+PS+ EM	33.00	36.00	39.00	48.00	44.00	35.00	32.00	35.00	50.20	55.00	51.00	50.00	**44.25**
Means	**27.80**	**29.60**	**31.40**	**34.40**	**36.40**	**30.20**	**26.20**	**28.70**	**42.20**	**45.20**	**42.80**	**50.00**	**-**

CD (0.05)

Treatment = 0.47 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.73 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 1.63 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 9

Population of total actinomycetes (x 10^7 g^{-1}) during the decomposition of leaf litter of *Salix alba*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	14.00	15.00	17.00	18.00	20.00	15.00	12.00	14.00	22.00	25.00	29.00	31.00	**20.83**
AZ	16.00	17.00	18.00	21.00	22.00	17.00	14.00	17.00	26.00	29.00	31.00	33.00	**23.16**
PS	17.00	18.00	20.00	22.00	24.00	20.00	17.00	20.00	28.00	30.00	32.00	36.00	**24.83**
EM	19.00	22.00	26.00	28.00	30.00	23.00	19.00	23.00	33.00	37.00	39.00	41.00	**30.16**
AZ+PS+ EM	21.00	24.00	26.00	30.00	32.00	27.00	21.00	25.00	35.00	39.00	41.00	46.00	**32.33**
Means	**17.40**	**19.20**	**21.40**	**23.80**	**25.60**	**21.40**	**16.20**	**18.80**	**28.80**	**32.40**	**34.40**	**37.40**	**-**

CD (0.05)

Treatment = 0.46 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.72 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 1.61 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms

Table 10

Population of total actinomycetes (x 10^7 g^{-1}) during the decomposition of leaf litter of *Salix fragilis*

Treatment	2006						2007						Mean
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	
Control	14.00	15.00	18.00	20.00	21.00	18.00	13.00	15.00	25.00	29.00	31.00	34.00	**22.13**
AZ	17.00	19.00	21.00	23.00	24.00	21.00	15.00	18.00	28.00	31.00	34.00	35.00	**25.58**
PS	19.00	21.00	23.00	25.00	27.00	23.00	17.00	21.00	30.00	33.00	35.00	37.00	**27.38**
EM	21.00	24.00	28.00	30.00	31.00	27.00	19.00	23.00	35.00	39.00	41.00	44.00	**32.08**
AZ+PS+ EM	23.00	26.00	28.00	31.00	33.00	30.00	21.00	26.00	37.00	41.00	44.00	48.00	**34.08**
Means	**18.80**	**21.00**	**23.60**	**25.80**	**29.80**	**24.70**	**16.60**	**21.80**	**30.60**	**34.73**	**36.80**	**39.60**	**-**

CD (0.05)

Treatment = 0.51 Control = No inoculant AZ = *Azotobacter chroococcum*

Month = 0.79 PS = *Pseudomonas fluorescens* EM = Effective microorganisms

Treatment x month = 1.81 AZ+PS+EM= *Azotobacter chroococcum* + *Pseudomonas fluorescens* + Effective microorganisms