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Decomposition of potato litter in relation to microbial population and plant nutrients under field conditions

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With 8 figures

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1. Introduction

Decomposition of litter is a natural process responsible for the breakdown of complex organic compounds. During the process, inorganic minerals locked up in organic residue are released making them available to the growing plants. Litter and humus are chemical carriers of nutrients and therefore, rate of their decomposition determines the rate of nutrient cycling in the system. The phenomenon assumes added significance in agroecosystems where crop litter is usually a principal amendment applied to the soil and plays an important role in maintaining soil fertility affecting both the physical structure of the soil and its nutrient status.

Most chemical degradation of litter is carried out by heterotrophic microorganisms. The quantity and quality of microorganisms colonising organic matter is determined by the physical structure and chemical composition of the substrate and the climate of the site (HOLLAND & COLEMAN, 1987). The activity of microorganisms and various physico-chemical agencies bring about change in the structure and chemical composition of organic matter which in turn determines species composition of late colonizing microorganisms. Microbial succession continues until all the organic substances are mineralised.

The chemical composition of the litter is an important factor regulating the rate of decomposition (BERG & STÅÅF, 1980; PARKER *et al.*, 1984; SCHWINTZER, 1984). Nitrogen, tannin and lignin contents and the nature of chemical bonds which attach the elements to the organic matter affect the rate of decomposition of plant litters (HARRISON, 1971; MEENTMEYER, 1978; STÅÅF & BERG, 1982). Stem and leaf of potato contain higher proportion of parenchymatous and collenchymatous tissue and higher amount of carbohydrates and minerals than the roots (HARRIS, 1978) which influence the activity of the microorganisms and thereby the rate of decomposition. The rate of decomposition is also influenced by moisture, temperature and the types of microorganisms involved in the process (ORBORNE & MACAULEY, 1988).

A significant part of leaf, stem and root litter of potato is amended to the agricultural soils. As most plant parts remain green and live at the time of harvest of tubers, the potato litters are generally green at the time of amendment and therefore, the potato litter differs to a great extent from the wheat, maize, barley and rice straw. A perusal of literature shows that, whereas there have been some studies on the decomposition of straw of various cereals (LADD, 1981; DKHAR, 1983; SAIN, 1984; CHRISTENSEN, 1985; BARUAH *et al.*, 1986) there have been no studies on the decomposition of potato litter.

The present study deals with the decomposition rate, changes in chemical composition and microbial population associated with decomposing litter of potato.

Table 1. Rainfall, temperature and relative humidity of the site during the study period.

Months	Rainfall [mm]	Mean temperature [°C]		Mean relative humidity [%]	
		Maximum	Minimum	Morning hours (8.30)	Evening hours (17.30)
Dec. 85	4.0	16.0	2.3	71	87
Jan. 86	10.0	14.7	1.2	72	89
Feb. 86	5.2	16.7	1.9	59	71
Mar. 86	13.4	20.1	7.7	44	56
Apr. 86	143.4	20.0	11.1	74	78
May. 86	246.5	21.3	11.7	72	78
Jun. 86	274.8	22.9	15.8	84	88
Jul. 86	279.0	21.7	16.4	92	90
Aug. 86	215.0	21.5	15.7	80	85

2. Materials and methods

2.1. Site description

The study was conducted in the farms of Central Potato Research Station, Shillong (altitude 1,706 m, latitude 25°34′ N, longitude 91°56′ E). The climate of the area is subtropical. Annual precipitation during the study period was 1,580 mm and most rainfall occurred between April and September. The minimum and maximum ambient temperature was 0.5 °C and 23 °C in the month of January and June respectively (table 1). The top soil is sandy loam (Sand 72%, Silt 10% and Clay 18%). The range of various physico-chemical parameters of soil during the study period was: pH 4.1–4.6; moisture 20%–39%; organic carbon 2.9–3.4%; total nitrogen, 0.12–0.20%; available phosphorus 0.04%–0.06% and potassium, 0.02–0.09%.

2.2. Rate of litter decomposition

The litter bag technique was used to study the rate of decomposition (Bocock *et al.*, 1960). Plastic nets of 1 mm mesh size were stitched into bags (20 cm × 20 cm). Leaves, stems and roots of potato plants were collected immediately after being harvested without exposure to rain between harvesting and collection. The straw was air dried for three weeks and xeromass *S.Str.* (60 °C for 48 h) correction factor was determined.

For each litter type, 10 g of air dried litter was placed separately in each of 40 litter bags. The bags containing leaf and stem litters were placed randomly in the field, while those containing root litter were buried under the soils at a depth of 5.0 cm in the same field. The collection of litter bags was done at monthly interval for 8 months. At each sampling time 5 replicate bags of each litter type were collected aseptically in sterilized polythene bags and were brought to the laboratory. Three replicate bags were used for the determination of mass loss. The adhering extraneous matters visible to unaided eyes were carefully removed from the litters by brushing and washing in a 200 µm mesh sieve and each litter sample was dried (60 °C) to constant mass. The mass loss of litter was calculated on the basis of xeromass *S. Str.*.

2.3. Isolation of fungi and bacteria

The litter from two replicate bags specifically put out for isolation of bacteria and fungi was washed gently in sterilized water to remove surface contaminations. The litter was cut into small pieces of 10 mm and added into a 250 ml conical flask, containing 100 ml of sterilized distilled water and then shaken on horizontal shaker (120 throws min^{-1} and 1.5 cm displacement) to form a homogenous suspension. The dilution plate method was used for the isolation of litter microflora (fungi, bacteria). A minimum of 10^{-4} dilution was used for bacteria and 10^{-3} for the fungi. A portions of 0.5 ml of litter suspension from suitable dilution was spread onto each of the sterilized petriplates containing 20 ml of cooled soldified rose bengal agar (Martin, 1950) and nutrient agar (Johnson & Curl, 1972) media for isolation of fungi and bacteria respectively. The initial microbial population associated with the litters was estimated before putting the bags in the field. For identification of the fungi the books consulted were those of Barnett & Hunter (1972), Subramanian (1971) and Domsch *et al.* (1980). No attempt was made to identify the bacteria.

2.4. Chemical analysis of litter and soil

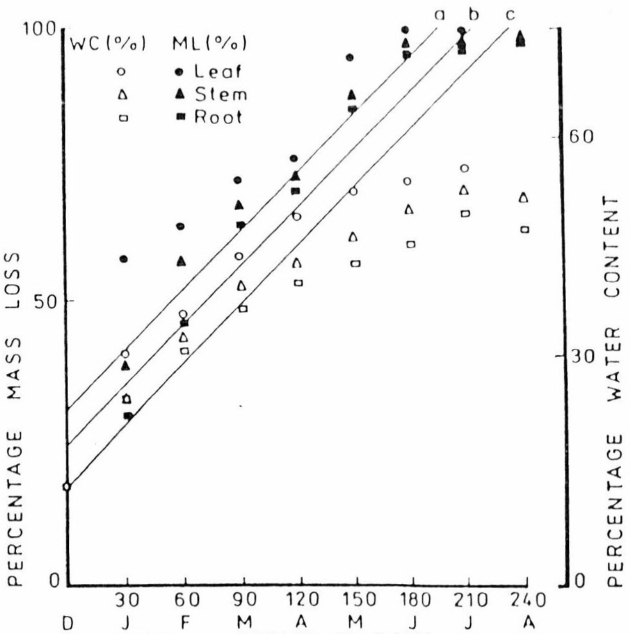
For the chemical analysis the litter samples were milled in the laboratory and analysed for total contents of the elements C, N, P, K, Ca and Mg. Organic carbon was estimated by the ignition method. Nitrogen was determined by semi-micro Kjeldahl procedure (ALLEN, 1974). After an acid wet oxidation in $HNO_3 + H_2SO_4 + HClO_4$, analyses were performed for phosphorus by the sulphomolybdic acid method (JACKSON, 1973) and for potassium by flame photometric procedure. Calcium and magnesium were determined by EDTA titration method (ALLEN, 1974). Organic carbon, total nitrogen, available phosphorus and exchangeable potassium of soils were determined by the WALKLEY & BLACK's (1934) method, semi micro Kjedahl method (ALLEN 1974), sulphomolybdic acid method (JACKSON, 1973) and flame photometer method respectively. The pH was measured in a soil and water mixture (1:5 m/m) using an electrical pH meter. Moisture content was assessed by the oven dry method at 105 °C.

2.5. Statistical analysis

Simple linear regression model of the type y = a + bx (y = percentage litter mass loss; x = period of exposure in days) was used for the analysis of relationships between the mass loss and period of exposure. Same regression model was also used to describe the relationship between the changes in C, N, P, K, Ca and Mg contents of the litter and period of exposure (SNEDECOR & COCHRAN, 1967).

3. Results

The percentage mass loss of the litter is given in fig. 1. Loss in mass of leaf during the first month was 58.60%; afterwards the rate of loss was slow but uniform, however, between the months of April and May (after 150 d) mass loss increased considerably. In case of stem and root



a: $y = 28.908 + 0.395x$ $r = 0.891$ $(P < 0.05)$
b: $y = 24.033 + 0.375x$ $r = 0.930$ $(P < 0.05)$
c: $y = 17.048 + 0.404x$ $r = 0.955$ $(P < 0.05)$

Fig. 1. Percentage mass loss and water content of potato leaf, stem and root litters after different periods of decomposition.

litter mass loss during the first month was 39.21 and 29.15% and afterwards monthly differences in mass loss were less pronounced. In the case of all the three litter types the mass loss was rapid during the first month which slowed down during subsequent periods and the rate of mass loss increased during the rainy season. In general, the leaves decomposed faster than stems and roots.

The decay rate coefficient (k) was calculated by using the model proposed by OLSON (1963). The values obtained for daily decomposition coefficient and time required for 95% and 99% mass loss of leaf, stem and root litters are given in table 2.

Table 2. Decay rate coefficient (k) and time required for half life, 95% and 99% mass loss of the 3 litter types.

Types of litter	k value day^{-1}	half life (days)	95% mass loss (days)	99% mass loss (days)
Leaf	0.275	23.21	108.97	167.09
Stem	0.019	32.68	153.45	235.30
Root	0.017	38.64	167.30	256.53

As fig. 2 showed initially the number of fungal propagules and bacteria was low but after the spreading of bags in the field a rapid increase in these numbers was noted. Maximum fungal propagule and bacterial numbers on leaf litter were recorded after 180 d. Generally, stem litter harboured less fungal and bacterial numbers than the root and leaf litter. A peak in fungal propagules and bacterial numbers in case of stem and root was found after 210 d which declined later.

The composition of fungal species colonising the litters changed with time (table 4). From the litter *Mucor hiemalis*, *M. plumbeus*, *Penicillium chrysogenum* and *Rhizopus oryzae* were isolated initially. *Fusarium moniliforme*, *Mucor spp.*, *Penicillium spp.*, *Rhizopus oryzae*, *Rhizopus stolonifer* and some sterile forms were isolated sporadically. Among late colonizers *Cladosporium*

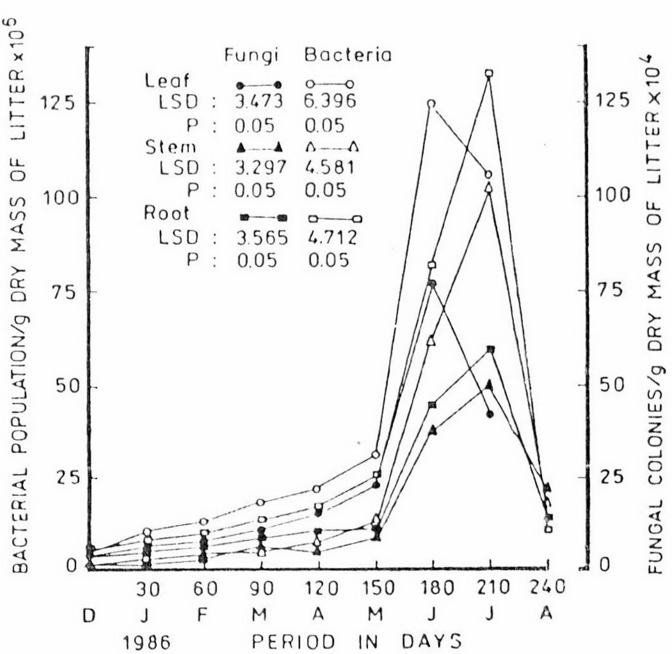


Fig. 2. Population of fungi and bacteria associated with potato litter at different periods of decomposition.

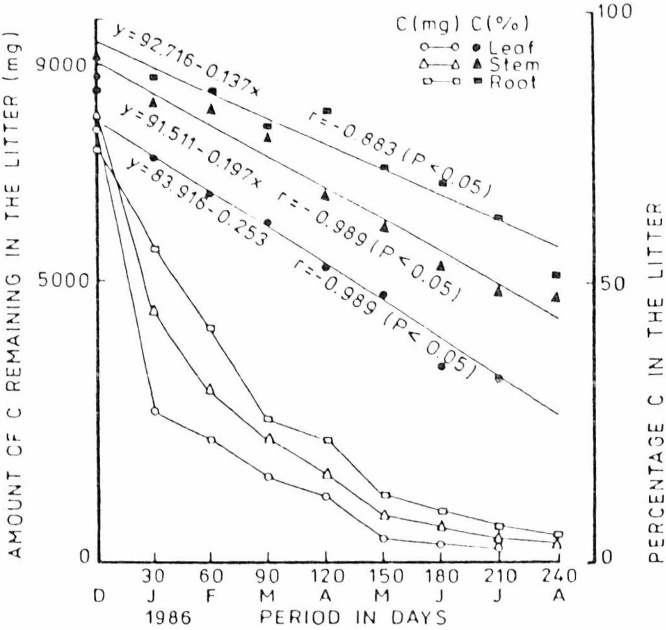


Fig. 3. Percentage carbon concentration and total amount of carbon (mg) remaining in the potato litter at different periods of decomposition.

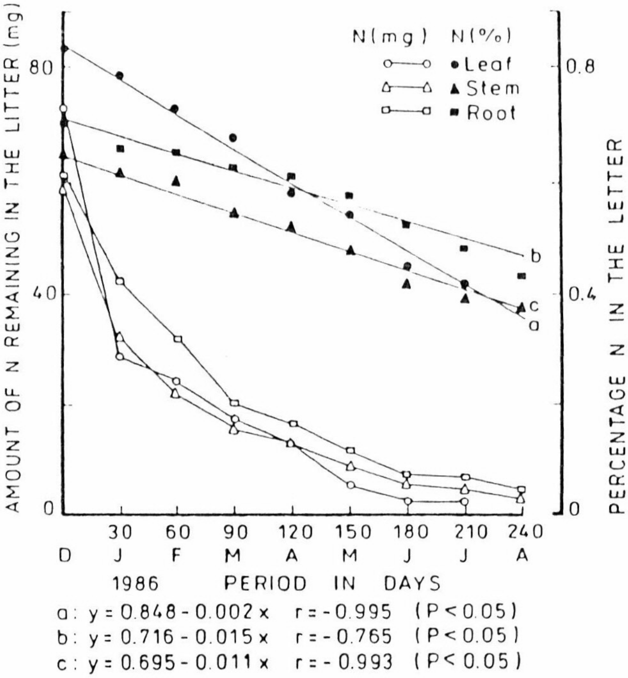


Fig. 4. Percentage nitrogen concentration and total amount of nitrogen (mg) remaining in the potato litter at different periods of decomposition.

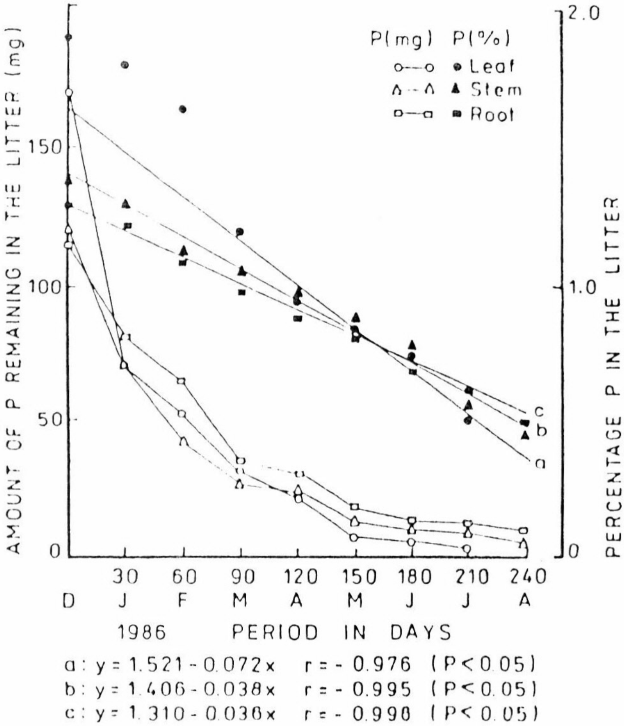


Fig. 5. Percentage phosphorus concentration and total amount of phosphorus (mg) remaining in the potato litter at different periods of decomposition.

sp., *Mucor mucedo, Nannizzia incurvata, Alternaria sp., Arthroderma curreyi, Chaetomium cochliodes, Torula herbarum* and *Wardomyces simplex* appeared consistently from 120 to 210 d.

The pattern of plant nutrient change during litter decomposition differed markedly with the element and litter type. Initially, the percentage carbon content in leaf litter was 88% and after decomposition at the end of study only 33% carbon remained (fig. 3). In case of root and stem at the end of study 38% and 60% carbon content was found. Maximum initial amount of carbon was found in leaf litter. Initially, the nitrogen content in leaf litter was 0.83% and the content remaining after decomposition was 0.43%. In stem and root initial concentration of nitrogen was 0.65% and 0.70% respectively and after 240 d decomposition it was 0.39% and 0.44% (fig. 4). Initially P content in leaf, stem and root litter was 1.94%, 1.40% and 1.30%. The maximum P was recorded in leaf litter and the minimum in root litter (fig. 5). After 210 d phosphorus content in leaf was 0.55% whereas in stem and root after 240 d it was 0.47%. Like the N and P, maximum K was estimated from leaf litter followed by stem and root (fig. 6). Maximum leaching of K at the end of study was recorded from leaves (85.5%) followed by stems and roots (75.5% and 83%) respectively. In the case of leaf litter the initial Ca content was 2.33%. After 30 and 90 d little accumulation was noticed. The maximum amount of Ca was found in leaf litter and minimum in root litter. The absolute values of calcium at the end of study was highest in root litter and lowest in leaf litter (fig. 7). The percentage Mg in leaf, stem and root litter was 0.65%, 0.55% and 0.51% respectively. After decomposition at the end of study it dropped to 0.35%, 0.35% and 0.26%. The maximum concentration of Mg was recorded in leaf litter followed by stem and root (fig. 8). Carbon and element ratios are given in table 3. The C/N ratio decreased at the end of the study period as compared with initial C/N ratio in all the 3 litters. Carbon and elements ratios in the cases of P, K, Ca and Mg did not show any regular pattern.

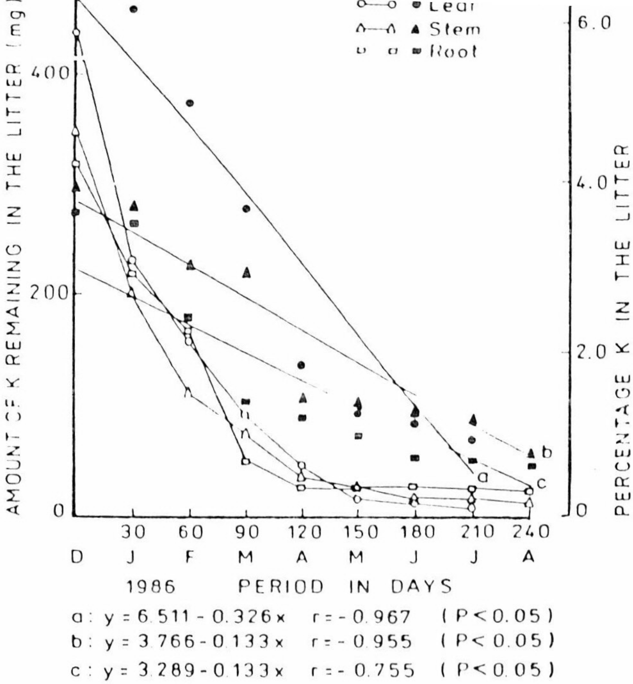


Fig. 6. Percentage potassium concentration and total amount of potassium (mg) remaining in the potato litter at different periods of decomposition.

Table 3. Carbon/element ratios in the decomposing litters of potato at different periods (L – Leaf, S – Stem, R – Root)

Day/Months	C/N			C/P			C/K			C/Ca			C/Mg		
	L	S	R	L	S	R	L	S	R	L	S	R	L	S	R
0, D	106	141	121	45	65	65	14	23	24	36	40	56	135	167	164
30, J	88	134	134	38	63	73	12	22	25	24	42	69	121	160	180
60, F	92	136	132	41	71	78	13	27	35	29	48	61	124	167	186
90, M	80	138	124	50	73	77	16	29	55	25	64	51	124	164	175
120, A	90	124	138	56	68	92	27	44	69	26	66	62	115	146	193
150, M	87	127	141	56	70	96	36	43	79	25	63	68	111	148	213
180, J	77	123	146	46	68	101	31	40	100	20	63	78	89	139	237
210, J	76	122	129	60	85	103	35	44	88	23	70	109	94	136	213
240, A	–	120	115	–	98	107	–	47	85	–	78	95	–	134	196

4. Discussion

The slopes of regression in fig. 1 indicate a significant positive relationship between period of exposure and rate of mass loss. General pattern of mass loss was also similar in all the three litter types. The rate of decomposition was rapid with more than 90% of each litter type being decomposed within 8 months. Sain (1984) reported 94% mass loss of rice straw in a year.

Table 4. Population of fungal species (g^{-1} dry litter $\times 10^{3}$) associated with decomposing litter of potato.

Isolates	Months/days								
	Dec. 0	Jan. 30	Feb. 60	March 90	April 120	May 150	June 180	July 210	Aug. 240
	Leaf								
Cladosporium sp						79.9	199.9	48.0	
Fusarium moniliforme SHELD.	–	5.6	–	14.0	23.5	42.6	230.7	–	–
Mucor circinelloides VAN TIEGH.	–	–	12.0	21.0	15.6	–	–	–	–
Mucor hiemalis WEHMER	7.0	16.9	9.0	28.0	15.6	37.3	76.9	–	–
Mucor mucedo MICH.	–	–	–	–	–	–	–	48.0	–
Mucor racemosus FRES.	–	–	–	–	–	47.9	–	–	–
Nannizzia incurvata STOCKED		–	–	–	–	–	–	32.0	–
Penicillium chrysogenum THOM.	3.5	–	18.0	21.0	27.4	21.3	184.6	96.0	–
Rhizopus oryzae WENT & PRINSEN	7.0	11.2	12.0	17.5	15.6	–	–	–	–
Rhizopus stolonifer EHRENB.		8.4	15.0	17.5	47.0	–	–	–	–
Sterile	–	–	–	–	–	–	76.9	80.0	–
	Stem								
Alternaria sp	–	–	–	–	–	–	–	14.3	–
Arthroderma curreyi BERK.	–	–	–	–	–	–	–	57.5	–
Chaetomium cochliodes PALL.	–	–	–	–	–	–	–	–	173.0
Cladosporium epiphyllum PERS.	–	–	–	–	–	19.0	100.0	115.1	–
Fusarium moniliforme SHELD.	–	–	–	–	13.9	28.5	87.5	86.3	–
Mucor circinelloides VAN TIEGH.	–	5.2	12.4	13.1	6.9	9.5	12.5	14.3	–
Mucor plumbeus BONORD	9.1	5.2	9.3	13.1	–	–	–	–	–
Mucor racemosus FRES.						14.2			–
Penicillium sp.								4.3	3.3
Penicillium chryosogenum THOM.	4.5	2.6	6.2	13.1	13.9	14.2	150.0	100.7	3.3
Penicillium fellutanum BIOURGE	–	–	6.2	9.8	–	–	–	4.3	–
Rhizopus oryzae WENT & PRINSEN	–	–	–	–	10.4	–	–	–	–
Rhizopus stolonifer EHRENB.	–	–	–	–	6.9	–	–	–	–
Trichoderma viride (PERS.) GRAY	–	–	–	–	6.9	–	–	–	–
Sterile	–	–	–	–	–	–	50.0	28.7	93.3
	Root								
Arthrobotrys superba CORDA	–	–	–	–	–	–	–	–	18.1
Cladosporium sp.	–	–	–	–	–	20.2	79.9	–	–
Fusarium culmorum SACC.	–	–	–	–	–	–	–	–	81.8
Fusarium moniliforme SHELD.	–	–	2.8	10.0	7.3	55.6	119.9	144.0	–
Fusarium merismoides CORDA	–	–	–	–	–	–	39.9	–	–
Mucor hiemalis WEHMER	6.8	15.0	22.5	23.5	29.3	15.1	–	–	9.0
Mucor plumbeus BONORD.	–	10.0	16.9	26.8	7.5	–	–	–	–
Penicillium chrysogenum THOM.	3.4	7.5	5.6	10.0	–	–	–	–	–
Penicillium lanosum WESTLING.	–	–	–	–	18.3	119.0	110.9	32.0	–
Rhizopus oryzae WENT & PRINSON	–	–	–	–	25.6	30.3	–	–	–
Torula herbarum PERS.	–	–	–	–	–	–	–	–	9.0
Trichoderma viride PERS.	–	–	–	–	–	–	–	–	18.1
Wardomyces simplex SUGIYAMA		–	–	–	–	–	–	–	45.4
Sterile							93.3	368.0	9.0

MANGENOT (1966) found 85–90% mass loss of *Melandrium* litter in 130 d and attributed major mass loss to the activities of saprophytes. In the present study the faster mass loss of leaf litter might be due to higher activities of fungi and bacteria on leaf litter as compared to stem and root litter. The fungal population estimated by the dilution plate method is more selective for spores rather than active hyphae, nevertheless the increase in propagules may well reflect increased

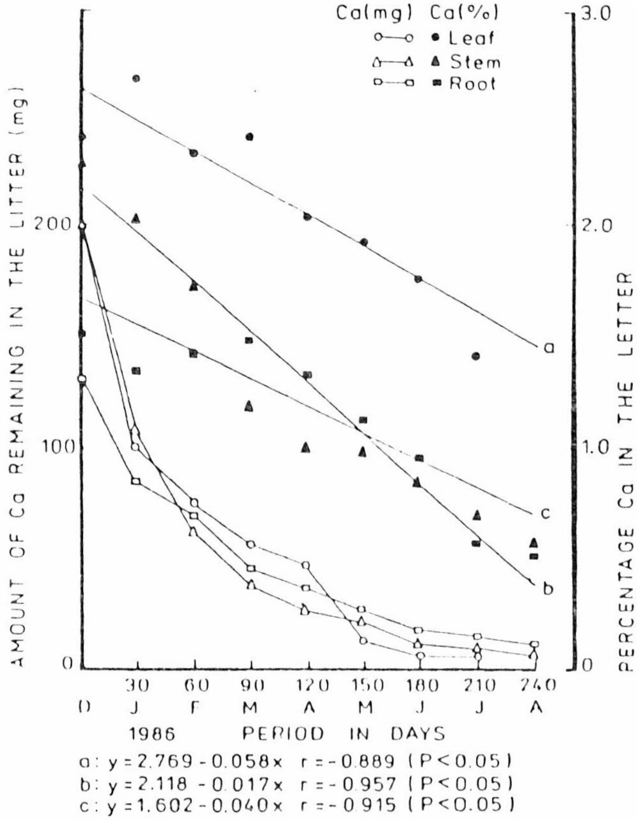


Fig. 7. Percentage calcium concentration and total amount of calcium (mg) remaining in the potato litter at different periods of decomposition.

fungal activity (fig. 2). In May an increase in mass loss was found which may again be due to increase in the activity of bacteria and fungi during the same period.

The concentration of mineral nutrients in the litter also plays an important role in decomposition. The fast mass loss of leaf litter compared with stem and root litters could be attributed to the higher concentration of minerals (C, N, P, K, Ca, Mg) in leaf. It is reported that the higher the concentration of minerals the faster the rate of mass loss (BERG & STÅÅF, 1980). CHRISTENSEN (1986) found that high nitrogen concentration (0.92%) was responsible for the greater loss in mass (44%) during the first month of barley litter decomposition. The results suggest that litter decomposition is governed by the concentration of mineral nutrients. During the process of decomposition carbon is used as an energy source by decomposers while nitrogen is assimilated in protein and other compounds. Thus high nitrogen content in the original material promotes decomposition at least in early stages. That litter contains a higher amount of nitrogen initially which declines during decomposition is reported by CHRISTENSEN (1985). Initially the concentration of nitrogen was more in root as compared to stem, however, the mass loss was higher in stem. JAWSON & ELLIOT (1986) reported higher concentration of nitrogen in roots than in straw while the carbon concentration was high in straw. They found faster mass loss in straw than in root. C/N ratio also plays an important role in mass loss and generally the rate of mass loss is faster in materials with high C/N ratio, (BERG & STÅÅF, 1980). As mass loss increased the C/N ratio decreased, a phenomenon which has been reported by SCHLESINGER & HASEY (1981) and

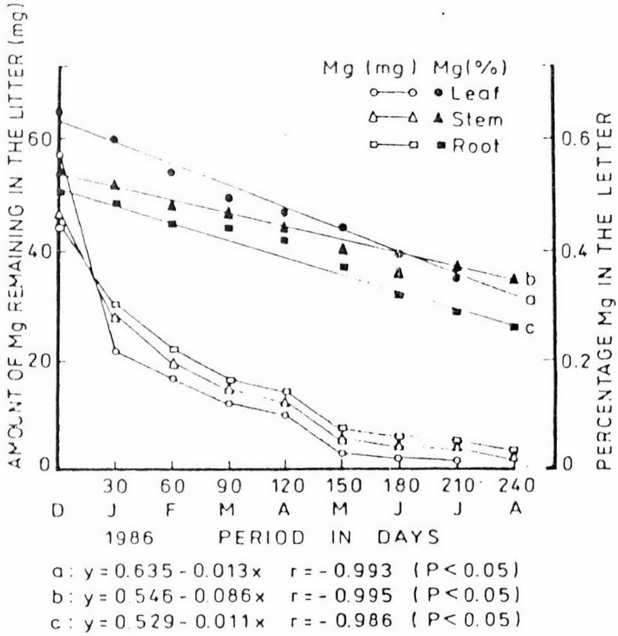


Fig. 8. Percentage magnesium concentration and total amount of magnesium (mg) remaining in the potato litter at different periods of decomposition.

MULLER & BERG (1988). The carbon/element ratios did not show any regular pattern in leaves, stems and roots which is in conformity to the study of STÅÅF & BERG (1982). After spreading the litter bags in the field the sudden loss in mass during the first month may be due to leaching of water soluble compounds. The initial loss was more pronounced in the case of leaf litter than for stems and roots and this may be due to higher percentage of parenchymatous tissue in the case of leaf litter (HERING, 1965). The relationship between percentage C, N, P, K, Ca and Mg content of the litter and period of exposure was analysed by using a simple linear regression model. A significant negative relationship was observed in the case of all the elements and each of the litter types indicating that throughout the study period the elements were released steadily (fig. 3–8).

Increase in the number of bacteria and fungi during the later period may be due to improvement of moisture level, moderation of temperature and higher relative humidity (table 1) which favoured the build up of the microbial community. The maximum microbial population was found in leaf litter followed by stem and root litters. It may be due to the higher concentration of minerals in leaf litter as compared to stem and root litter. The rate of nutrient loss was also related to the microbial population as during period of higher microbial population the nutrient loss was maximum. It has been established that the fungal mycelium when breaking the litter substances, simultaneously utilise it for their own growth thereby retaining some amount of mineral in their body. These elements are then released slowly after the death of the fungal body usually in ionic forms (WITKAMP, 1971). The fungal species composition is regulated by climatic factors and nutrient concentrations in the substrates (ADEDEJI, 1986). SADASIVAN (1939) found that *Fusarium* sp. and *Mucor sp.* were more abundant at the initial stage of decomposition of wheat straw but later the fungal population was dominated by *Penicillium spp.* Cellulose decomposition capability of *Penicillium* is well known. Possibly the sterile forms isolated during later stage of decomposition belong to the class basidiomycetes which do not produce fruiting bodies on the agar media (MISHRA &

TIWARI, 1984). GARRETT (1963) reported that fungi which are responsible for the decomposition of lignin appear in the last stage of decomposition and most of the basidiomycetes come in this category.

Some basic principles for element dynamics in decomposing litter have been outlined by SWIFT *et al.* (1979). According to their model the release of inorganic forms of an element will occur only as long as the carbon/element ratio of resource stays below a level where it becomes limiting to the organisms decomposing it. In a litter structure for which the carbon/element ratio exceeds this level, the element would be retained and possibly imported to it, until the critical level is reached and then released in proportion to mass loss (BERG & STÅÅF, 1981). The element in surplus (i.e. those where the initial carbon/element ratio are below the limiting values) would then be in a release phase. In the present study, however, the carbon/element ratios never appeared to be limiting as the rate of decomposition was steady and the accumulation of the element was not observed (table 3). Thus, the present study shows that complete recycling of nutrients from the fresh potato litter will take less than one year.

5. Acknowledgements

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SHUKLA, A. K., B. K. TIWARI & R. R. MISHRA, 1990. Decomposition of potato litter in relation to microbial population and plant nutrients under field conditions. Pedobiologia **34**, 287–298.

The study on decomposition of leaf, stem and root litter of potato was carried out by using the plastic net bag technique. It was found that the rate of decomposition was dependent on the chemical composition of litter and associated microbial population. Mass loss of leaf litter was faster than stem and root. Higher concentration of C, N, P, K, Ca and Mg was found in leaf litter as compared to the stem and root. The concentration of elements decreased with time. Highest microbial population on leaf litter was found in the month of June while in the case of stem and root the maximum microbial population was recorded in the month of July. The study on the rate of decomposition and loss of elements from potato litters demonstrated that the turnover of nutrients will take less than one year.

Key words: Potato litter, decomposition, bacteria, fungi, C, N, P, K, Ca and Mg.

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