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Releasing pattern of nitrogen, phosphorus and potassium from decomposing litter in arid to semi-arid climatic conditions

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Abstract. The pattern of release of N, P and K from decomposing leaf-litter of 3 species was investigated. These elements were continually released in all 3 litter types. Among the 3 elements studied, K was released rapidly in all the 3 litter types. No immobilization phase was evident.

Keywords. Nitrogen; phosphorus; potassium; releasing pattern; immobilization.

1. Introduction

Several studies on nutrient release from decomposing litter of different species are available (Gosz *et al* 1973; Howard and Howard 1974; Parnas 1975; MacLean and Wein 1978; Swift *et al* 1979; Jorgensen *et al* 1980; Berg and Staaf 1981; Staaf and Berg 1982; Pandey and Singh 1984). Swift *et al* (1979) described 3 phases in the release pattern of nutrients from litter, viz leaching, accumulation (immobilization) and net release. The decomposition rates of *Datura inoxia*, *Solanum sysimbrifolium* and mixed grasses were earlier described in detail by Bhatt *et al* (1985). In this paper the dynamics of N, P and K in decomposing leaf-litter of the same 3 species is being described, and as to how they are regulated by biotic and abiotic factors of the environment.

2. Materials and methods

2.1 *The study area*

The study was conducted at Rajkot (N 20° 58′ and E 70° 20′) in a grazing land ecosystem, dominated by *Dichanthium annulatum* and *Aristida royleana*. *D. inoxia* and *S. sysimbrifolium* occupy special niches in the ecosystem. The soils are silty-clayey loams derived from Basalt (Deccan trap).

2.2 *Climate*

The mean annual precipitation at Rajkot is 675 mm. The mean maximum temperature ranges from 36–44°C and the mean minimum from 7·5–23·5°C. The year is divisible into rainy (mid June to September), post-monsoon (October–November), winter (December–February) and summer seasons (March–early June).

2.3 *Litter decomposition*

For the decomposition study, newly senesced leaves of *D. inoxia*, *S. sysimbrifolium* and mixed grass litter were collected in polyethylene bags. The mixed grass litter included *A. royleana*, *D. annulatum* and *Melanocenchris jacquemontii*. The litter samples were air dried. Litter bags of galvanized wire netting of the size 15 × 10 cm with 1 mm mesh size were used and 5·0 g of litter were kept in the bags separately. The litter bags were randomly placed on the floor on 16 June 1980 and sampling was done at fortnightly intervals. Three litter bags of each litter type were retrieved randomly on each sampling date for determining its moisture content and chemical composition, after oven-drying at 80°C to a constant weight. Before this, the material from individual bags was washed with a fine jet of water through a 100 μ mesh to get rid of contamination, if any. For the evaluation of density of microorganisms, two more litter bags of each litter type were randomly retrieved on each sampling date. The material from these bags was not washed but used directly. One g fresh weight of each litter type was mixed with 10 ml of sterile double distilled water in a test tube, from which dilutions series were prepared as described by Collins (1967). This was done by aseptically transferring 1–9 ml of sterile double distilled water in culture tubes. For enrichment and isolation of bacteria, actinomycetes and fungi; pourplate technique was employed. For this, two dilutions, i.e. 10^{-4} and 10^{-5} were arrived at, after testing different dilutions. 0·1 ml from these dilutions was inoculated in sterile petridish and the selective culture media were prepared and incubated at room temperature for 2–3 days. The number of microorganisms was obtained by multiplying the number of colonies with the dilution factor and is expressed per g of dry weight of litter. Topping's agar medium and glucose yeast extract agar medium were used for bacteria and actinomycetes, respectively, as suggested by Sheldon (1970). Sabouraud's (1910) agar medium was used for fungi. Soil temperature and moisture content were determined on each sampling interval. Soil moisture content is expressed as per cent of oven-dried soil after Misra (1968). The rate of CO_2 evolution from decomposing litter was determined *in situ* by inverted box method (Witkamp 1966).

The litter bags with residual material of each species were sampled randomly, oven-dried at 80°C to a constant weight and analysed for N, P and K. Total nitrogen was determined by micro-Kjeldahl method (Misra 1968); phosphorus, colorimetrically by chlorostannous reduced molybdophosphoric blue method (Jackson 1958); and potassium by flame photometry (Jackson 1958). The absolute content of the nutrients was computed by multiplying the dry weight of litter with the concentration of the element, at the respective sampling time. From these values, release of each nutrient during a specific period was calculated as cumulative release.

3. Results

3.1 *Nitrogen*

Initial N concentration was highest in *D. inoxia* litter followed by *S. sysimbrifolium* and mixed grass litter (table 1). The N concentration decreased during decomposition in all litter types. Thus, the immobilization phase was not present. The net

Table 1. Showing concentration of N, P and K in decomposing litter of the 3 species expressed in mg g^{-1}.

	D. inoxia			*S. sysimbrifolium*			Mixed grass		
Days	N	P	K	N	P	K	N	P	K
0	18·00	3·90	0·300	11·60	3·05	0·112	8·30	2·98	0·105
15	13·22	3·07	0·167	10·86	2·41	0·090	7·29	2·47	0·089
30	10·66	2·42	0·153	8·79	1·74	0·095	7·33	1·82	0·066
45	9·25	2·05	0·150	7·49	1·51	0·095	7·25	1·57	0·045
60	9·23	1·96	0·145	7·45	1·48	0·095	5·70	1·51	0·037
75	9·20	1·87	0·130	6·75	1·49	0·090	5·38	1·35	0·035
90	8·50	1·82	0·120	6·79	1·46	0·085	4·75	1·32	0·035
105	5·91	1·63	0·120	5·75	1·45	0·080	4·58	1·23	0·030
120	5·87	1·55	0·100	5·79	1·26	0·073	3·88	0·82	0·030
135	5·87	1·49	0·089	5·41	0·80	0·073	3·71	0·61	0·027
150	5·20	1·22	0·089	5·37	0·63	0·070	3·13	0·58	0·025

0 day, initial.

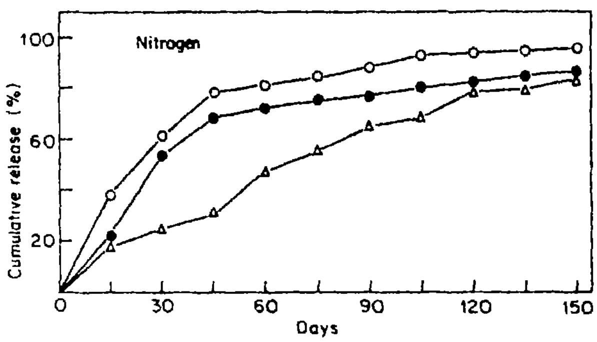

Figure 1. Cumulative release rate of nitrogen. (○), *D. inoxia* litter; (●), *S. sysimbrifolium* litter; (△), mixed grass litter.

release of N at different sampling intervals was maximum in *D. inoxia* litter followed by that of *S. sysimbrifolium*, and minimal in mixed grass litter (figure 1). The relationship between loss in litter weight and N release was significant at $P < 1\%$ for all the litter types (table 2). In all the litter types, a maximum release was recorded during the third sampling interval.

The relationship between N released and weight loss, in the 3 litter types was significant at $P < 1\%$ (figure 2). However, the slopes for 3 litter types (regression coefficients) did not differ significantly from each other, thus, suggesting a similar pattern of release of N in the 3 litter types. The relationships of N release with litter moisture, soil moisture, soil temperature, CO_2 evolution from decomposing litter and the number of microorganisms are summarised in table 2 and the results are self explanatory.

3.2 *Phosphorus*

Dynamics in the content and release of P in the 3 litter types followed similar patterns as that of N (figures 3 and 4) and the relationship between the released

Table 2. Correlation coefficient (r), intercept (a) and slope (b) between loss of nitrogen from decomposing litter of *D. inoxia*, *S. sysimbrifolium* and mixed grass, with various abiotic and biotic parameters.

Y	X	r	a	b	P
Loss of nitrogen from *D. inoxia* litter†	Weight loss of litter (g)	0·991	0·546	0·070	***
	Soil moisture content (%)	0·979	3·866	0·371	***
	Number of fungi (× 10^8) in litter	0·689	4·081	0·490	**
Loss of nitrogen from *S. sysimbrifolium* litter††	Weight loss of litter (g)	0·906	1·055	0·071	***
	Soil moisture content (%)	0·965	1·080	0·522	***
Loss of nitrogen from mixed grass litter†††	Weight loss of litter (g)	0·984	1·662	0·087	***
	Soil moisture content (%)	0·898	−3·203	0·590	***
	Soil temperature (°C)	−0·618	42·374	−0·401	**
	CO_2 evolution from litter (mg m^{-2} hr^{-1})	−0·561	11·456	−0·098	*

†Loss of nitrogen from *D. inoxia* litter extended NS relationships with litter moisture content (%), soil temperature (°C), CO_2 evolution from litter (mg m^{-2} hr^{-1}), number of bacteria from litter (× 10^8) and number of actinomycetes from litter (× 10^8).

††Loss of nitrogen from *S. sysimbrifolium* litter extended NS relationships with litter moisture content (%), soil temperature (°C), CO_2 evolution from litter (mg m^{-2} hr^{-1}), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).

†††Loss of nitrogen from mixed grass litter extended NS relationships with litter moisture (%), and numbers bacteria, actinomycetes and fungi from litter (× 10^8).

NS, Non-significant; *Significant at 10% P; **Significant at 5% P; ***Significant at less than 1% P.

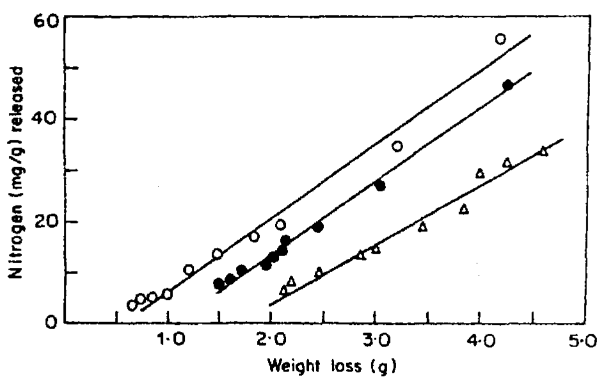

Figure 2. Relation between weight loss and release of nitrogen from decomposing litter. Details as in figure 1.

amount and weight loss was significant at $P < 1\%$ in all cases. Table 3 shows the relationship of release of P with biotic and abiotic factors and the results need no elaboration.

3.3 *Potassium*

The pattern of release of K during different sampling intervals is shown in figure 5. This element was released at a faster rate in all the 3 litter types, than N and P. The

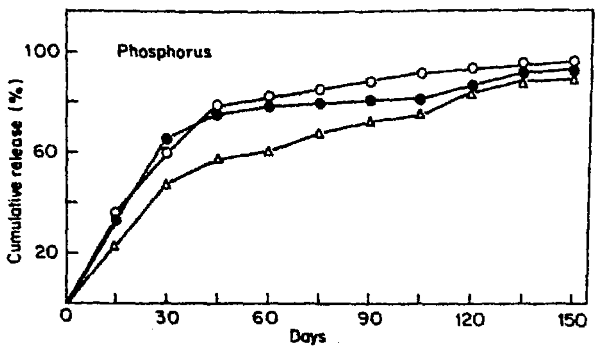

Figure 3. Cumulative release rate of phosphorus. Details as in figure 1.

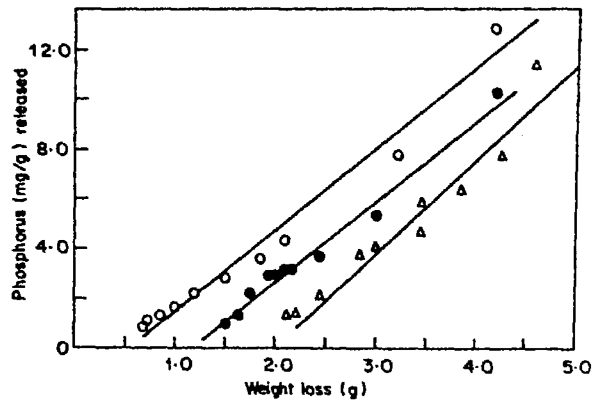

Figure 4. Relation between weight loss and release of phosphorus from decomposing litter. Details as in figure 1.

loss was more faster in *D. inoxia* followed by mixed grass litter. K content, in the 3 litter types, was significantly correlated ($P < 1\%$) with loss in weight of the litter (figure 6). However, in this case, slopes for the 3 litter types differed from each other, suggesting thereby, that the pattern of release of K in the 3 litter types was different.

The relationship of K release with the biotic and abiotic factors are summarised in table 4.

4. Discussion

Plant nutrients are released from the litter, either through physical leaching or by a break down of its components by soil organisms, and the rate of release is often largely governed by the decomposition rates. The results presented in the present study clearly revealed that none of the 3 elements studied (N, P and K) increased in their content throughout the study period, and there was a continuous release of these elements in all the 3 litter types investigated. In this respect, present observations differ from the model hypothesized by Swift *et al* (1979) who suggested that there is an accumulation phase (immobilization) before the release phase. Earlier, many

Table 3. Correlation coefficient (*r*), intercept (*a*) and slope (*b*) between loss of phosphorus from decomposing litter of *D. inoxia*, *S. sysimbrifolium* and mixed grass with various abiotic and biotic parameters.

Y	*X*	*r*	*a*	*b*	*P*
Loss of phosphorus	Weight loss of litter (g)	0·986	0·562	0·304	***
from *D. inoxia* litter†	Soil moisture content (%)	0·979	3·925	1·620	***
Loss of phosphorus	Weight loss of litter (g)	0·991	1·178	0·309	***
from *S. sysimbrifolium*	Soil moisture content (%)	0·956	2·031	2·267	***
litter††	CO_2 evolution from litter				
	(mg m^{-2} hr^{-1})	−0·520	9·548	−0·267	*
Loss of phosphorus	Weight loss of litter (g)	0·960	1·997	0·268	***
from mixed grass	Soil moisture content (%)	0·973	−1·915	2·010	***
litter†††	Soil temperature (°C)	−0·580	40·602	−1·183	*
	CO_2 evolution from litter				
	(mg m^{-2} hr^{-1})	−0·662	11·384	−0·365	**

†Loss of phosphorus from *D. inoxia* litter extended NS relationships with litter moisture (%), soil temperature (°C), CO_2 evolution from litter (mg m^{-2} hr^{-1}) and numbers of bacteria, actinomycetes and fungi (× 10^8) from litter.
††Loss of phosphorus from *S. sysimbrifolium* litter extended NS relationships with litter moisture (%), soil temperature (°C), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).
†††Loss of phosphorus from mixed grass litter extended NS relationships with litter moisture (%), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).
Notations same as in table 2.

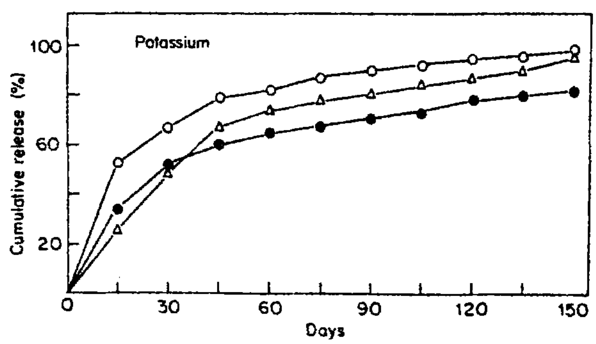

Figure 5. Cumulative release rate of potassium. Details as in figure 1.

workers reported an increase in the N content in decomposing leaf-litters (Anderson 1973; Aber and Melillo 1980, 1982; Melillo *et al* 1982) which is opposed to the results presented here (table 1). Hayes (1965) suggested the increase in N content to be due to either translocation or fixation by microorganisms. In the present study, however, no significant relationship was discerned between the nutrients' release and density of microorganisms.

The pattern of release of K presented in this study is in agreement with the general model proposed by Swift *et al* (1979) where a rapid loss of this element is reported. Such a rapid loss of K can be attributed to its susceptibility to leaching. This finding agrees with the earlier works of Staaf and Berg (1982) and Gosz *et al* (1973).

The pattern of release of N and P was strikingly parallel with the loss in weight of

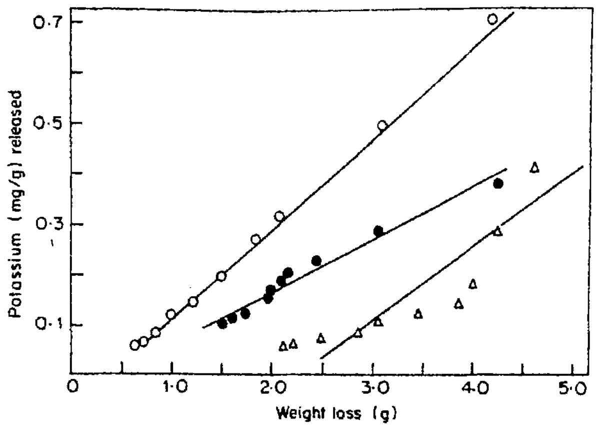

Figure 6. Relation between weight loss and release of potassium from decomposing litter. Details as in figure 1.

Table 4. Correlation coefficient (*r*), intercept (*a*) and slope (*b*) between loss of potassium from decomposing litter of *D. inoxia*, *S. sysimbrifolium* and mixed grass, with various abiotic and biotic parameters.

Y	*X*	*r*	*a*	*b*	*P*
Loss of potassium from *D. inoxia* litter†	Weight loss of litter (g)	0·999	0·371	5·562	***
	Soil moisture content (%)	0·991	2·916	29·560	***
	Soil temperature (°C)	0·525	27·144	4·736	*
Loss of potassium from *S. sysimbrifolium* litter††	Weight loss of litter (g)	0·986	0·418	9·451	***
	Soil moisture content (%)	0·992	−4·127	72·315	***
	Soil temperature (°C)	0·569	25·826	12·544	*
Loss of potassium from mixed grass litter†††	Weight loss of litter (g)	0·882	2·257	6·814	***
	Soil moisture content (%)	0·979	−0·685	55·992	***
	Soil temperature (°C)	−0·567	39·751	−32·125	*
	CO_2 evolution from litter (mg m^{-2} hr^{-1})	−0·609	11·029	−9·296	**

†Loss of potassium from *D. inoxia* litter extended NS relationships with litter moisture (g), CO_2 evolution from litter (mg m^{-2} hr^{-1}), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).

††Loss of potassium from *S. sysimbrifolium* litter extended NS relationships with litter moisture (%), CO_2 evolution from litter (mg m^{-2} hr^{-1}), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).

†††Loss of potassium from mixed grass litter extended NS relationships with litter moisture (%), and numbers of bacteria, actinomycetes and fungi from litter (× 10^8).

Notations same as in table 2.

the 3 litter types. At the end, it can be mentioned that a certain degree of predictability for the release rates of the 3 plant nutrients is possible from the data presented in this paper.

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References

Aber J D and Melillo J M 1980 Litter decomposition: measuring relative contributions of organic matter and nitrogen to forest soils; *Can. J. Bot.* **58** 416–421

Aber J D and Melillo J M 1982 Nitrogen immobilization in decaying hardwood leaf litter as a function of initial nitrogen and lignin content; *Can. J. Bot.* **60** 2263–2269

Anderson J M 1973 The break down and decomposition of sweet chestnut (*Castanea sativa* Mill.) and beech (*Fagus sylvatica* L.) leaf litter in two deciduous woodland soils. II. Changes in the carbon, hydrogen, nitrogen and polyphenol content; *Oecologia* **12** 275–288

Berg B and Staaf H 1981 Leaching, accumulation and release of nitrogen from decomposing forest litter. In Terrestrial nitrogen cycles. Processes, ecosystem strategies and management impacts; *Ecol. Bull.* **33** 163–178

Bhatt S C, Sarat Babu G V and Pandeya S C 1985 Leaf-litter decomposition in arid to semi-arid climatic conditions; *Proc. Indian Acad. Sci. (Plant Sci.)* **95** 409–415

Collins C H 1967 *Microbiological methods* (London: Butterworths) p 404

Gosz J R, Likens G E and Bormann F H 1973 Nutrient release from decomposing leaf and branch litter in the Hubbard Brook Forest, New Hampshire; *Ecol. Monogr.* **43** 173–191

Hayes A J 1965 Studies on the decomposition of coniferous leaf litter. I. Physical and chemical changes; *J. Soil Sci.* **16** 121–140

Howard P J A and Howard D M 1974 Microbial decomposition of tree and shrub leaf litter. I. Weight loss and chemical composition of decomposing litter; *Oikos* **25** 341–352

Jackson M L 1958 *Soil chemical analysis* (New Delhi: Prentice Hall of India Pvt. Ltd.)

Jorgensen J R, Wells C G and Metz L J 1980 Nutrient changes in decomposing loblolly pine-forest floor; *Soil Sci. Soc. Am. J.* **44** 1307–1314

MacLean D A and Wein R W 1978 Weight loss and nutrient changes in decomposing litter and forest floor material in New Brunswick Forest stands; *Can. J. Bot.* **56** 2730–2749

Melillo J M, Aber T D and Morature J F 1982 Nitrogen and lignin control of hardwood leaf litter decomposition dynamics; *Ecology* **63** 621–626

Misra R 1968 *Ecology workbook* (New Delhi: Oxford and IBH Publ. Co.)

Pandey U and Singh J S 1984 Nutrient changes and release during decomposition of leaf litter in a Himalayan Oak-conifer forest; *Can. J. Bot.* **62** 1824–1831

Parnas H 1975 Model for decomposition of organic material by microorganisms; *Soil Biol. Biochem.* **7** 161–169

Sabouraud R 1910 Maladies du Cuir Chevelu. III. Les Maladies Cryptogamiques Les Teignes. In *Methods in microbiology* (ed) C Booth (London and New York: Academic Press) pp 429–460

Sheldon A 1970 *Experimental microbial ecology*, (New York and London: Academic Press) p 236

Staaf H and Berg B 1982 Accumulation and release of plant nutrients in decomposing Scots pine needle litter. Long-term decomposition in a Scots pine Forest II; *Can. J. Bot.* **60** 1561–1568

Swift M J, Heal O W and Anderson J M 1979 *Decomposition in terrestrial ecosystems. Studies in ecology* (Oxford: Blackwell Scientific Publications Ltd.) Vol. 5

Witkamp M 1966 Rates of carbon dioxide evolution from the forest floor; *Ecology* **47** 492–494