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NUTRIENT STRUCTURE AND DYNAMICS IN A TEMPERATE GRASSLAND COMMUNITY OF WESTERN HIMALAYA (GARHWAL), INDIA

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SUMMARY

The purpose of this study was to ascertain the nutrient levels in the pasture components, and to estimate annual uptake, release and retention of nitrogen, phosphorus and potassium in a temperate grassland community of Western Himalaya (Garhwal) from June 1983 to June 1984. The surface soil (30 cm) contains larger quantities of nutrients than were held by the plant biomass. The quantity of N, P and K, taken up annually by plants was about 19.8, 3.7 and 28.8 kg/ha, respectively. Of this, about 10.2, 1.5 and 6.3 kg/ha respectively are released and about 9.6, 2.2 and 22.5 kg/ha are retained in the vegetative compartments.

INTRODUCTION

The mineral component of an ecosystem operates in a dynamic state through a series of inputs and outputs of the essential elements. Plants and soil are the sub-systems of this dynamic system and serve as storage compartments, while the atmosphere can be considered as an open reservoir. Fluxes of nutrients from plants are continuously transferred to soil via litter formation. The latter contains the basis of essential elements for the plants in an ecosystem (Billore and Mall 1976). The mobility of elements through the plant/soil/atmosphere continum constitutes nutrient cycling. Patterns of biological circulation of nutrients differ from polar to tropical latitudes (Rodin and Bazilevich 1967).

A review of literature reveals that considerable work has been done on the nutrient structure and its cycling in cropland and forest ecosystems (Nye 1961; Ovington 1965; Rodin and Bazilevich 1967; Woodwell and Whittaker 1968; Turvey 1974; Pemadasa 1981; Middleton 1982 and Dhasmana 1983) since Liebig (1940) postulated the theory of uptake and complete return of minerals. However, less work has been done on grassland (Allison 1965; Laudeleut and Germain 1954; Yamane and Sato 1961; Dahlman *et al.* 1967 and Bokhari and Singh 1974) and no data are available on the nutrient cycling in the grasslands of Western Himalaya.

The present study investigates the variation of nitrogen, phosphorus and potassium content in 4 vegetation compartments (*viz.* live green, standing dead, litter and underground) and the soil. It also evaluates the average level of these nutrients in plant components and soil, and proposes an annual nutrient budget by estimating annual uptake, release and retention for the temperate grassland community of Western Himalaya (Garhwal).

MATERIALS AND METHODS

The study area

The study area was on community lands of 'DHANGOO' block of the district Pauri Garhwal (Western Himalaya) (29° 38′N and 78° 38′E). The elevation of the study area ranges from 1800 to 2100 m above sea level. The total area under grass cover is approximately 66 km^2 which is generally used as grazing land by nomadic guzzars and by local inhabitants. The area has moderate to steep slopes with undulating topography. The zone has a temperate climate with mild summers (Champion and Seth 1968). The annual rainfall is 559 mm, with about 85% falling in July–September. Sandstones and metamorphic rocks are the characteristic geological formations (Audin 1937).

The soil was sandy, with a pH ranging from 5.1 to 6.3. The loam and clay percentage was found to decrease with depth. The soil was low in organic carbon, total nitrogen, phosphorus and potassium. The vegetation comprises of grasses with forbs and only scattered trees and shrubs. *Arundinella nepalensis* and *Heteropogon contortus* are the dominant grasses of the grazing land. The other grasses and forbs are *Cyperus rotundus*, *Chrysopogon montanus*, *C. zeylanicus*, *Setaria glauca*, *Arthraxon lancifolius*, *Eulalia trispicata*, *E. mollis*, *Alysicarpus buplsurifolius*, *Vicia hirsuta*, *Coleus forskohlii*, *Desmodium prostratum*, *Flemingia bracteata*, etc. The woody species are *Quercus incana*, *Rhododendron arboreum*, *Pinus roxburghii*, *Myrica indica*, and *Rubus ellipticus*.

The 2 dominant grasses made up 90% of the density of the total plant community during the experimental period. The other grasses occurred only in the rainy and winter seasons and the density was found to be very low.

Biomass sampling and estimation of nutrients

A 5 ha plot from the grazing land, homogenous in species composition, was fenced for the estimation of aboveground live, standing dead and belowground biomass component. The short term harvest method (Odum 1960) was employed for the biomass observations at 2-weekly intervals during the period of most rapid growth (July to September) and 4-weekly intervals during the slow period (October to June) for 1 year (June 1983-June 1984). Five quadrats of 1 x 1 m, sub-divided in to 25 x 25 cm segments were placed in the pasture on each occasion and 20 of these segments were cut. The harvested aboveground live and standing dead material was sorted separately into species. Litter was hand picked and processed through floatation. Belowground biomass was evaluated by excavating soil cores of 25 x 25 x 30 cm. The belowground parts were gently washed over a 40 mesh sieve with a fine jet of water to remove soil particles. Loss of water soluble nutrients like N and K, during washing the litter and underground material, was considered common to all samplings, but could not be estimated from our techniques. All the above samples thus obtained, were oven dried, at 80°C for 24 hours. Soil samples were collected separately on each sampling month by digging 25 x 25 x 30 cm pits at the same locality and packing the soil recovered in polythene bags for analysis.

Aliquots of the dried material collected on all occasions were then mixed and ground through a 200 mesh screen. Separate samples were prepared for the aboveground live, standing dead, litter and belowground components. Total nitrogen was determined by Kjeldahl method (Piper 1944). For phosphorus, the wet digestion method was followed for the digestion of material and then followed by the colorimetric ammonium molybdate solution method (Jackson 1962). Potassium was estimated by Flame Photometry method (Peach and Tracey 1956).

The soil samples were air dried and analysed for total nitrogen, available phosphorus and exchangable potassium. The nitrogen and phosphorus was estimated by the technique followed by Misra (1968). The potassium was analysed by Flame Photometry (Peach and Tracey 1956). The nutrient content per gram dry weight of soil was multiplied by the bulk density, and the results are expressed as $g/m^2/30$ cm.

RESULTS AND DISCUSSIONS

Chemical composition

Some variation in mineral content occurred in the aboveground live, standing dead, litter and belowground components of the community (Table 1). Generally, the aboveground live component contained the highest amount of nitrogen, phosphorus and potassium, followed by the belowground, standing dead and litter components. As the death and decay of the material proceeds, the content of all 3 elements decrease. The relative proportion of the various elements differ considerably in different plant components.

TABLE 1

Average percentage nutrients (± S.D.) of the plants (June, 1983–June, 1984) expressed on an oven dry weight basis for the temperate grassland community of Western Himalaya

Plant Part	Nutrient		
	Nitrogen	Phosphorus	Potassium
		(%)	
Aboveground photosynthetic	0.79 (± 0.15)	0.14 (± 0.03)	0.48 (± 0.34)
Standing dead	0.69 (± 0.12)	0.09 (± 0.01)	0.26 (± 0.08)
Litter	0.29 (± 0.08)	0.07 (± 0.03)	0.20 (± 0.16)
Belowground	0.78 (± 0.79)	0.10 (± 0.01)	0.42 (± 0.09)
Average	0.64 (±0.24)	0.10 (± 0.03)	0.34 (± 0.13)

Standing state of the nutrients in plants and soil

For vegetation, the average standing state refers to the individual nutrient amounts in the average (annual) biomass of the 4 compartments, and is presented in Table 2. The data reveals that maximum storage of nitrogen occurred in belowground parts, while the maximum phosphorus and potassium storage was in aboveground live component. The litter component had the lowest values of all the 3 nutrients.

Nutrient budget

The components of the present grassland community were arranged in a block and arrow model (Billore and Mall 1976), with each vegetational component considered as an independent compartment with an input and output (Fig. 1). The values in the rectangular boxes are the average standing states of the nutrients, and were obtained by multiplying the average compartmental biomass with appropriate nutrient equivalents. These standing states are not as informative as the annual transfer rates (shown in Fig. 1 by arrows between compartments) since they are only an approximate measure of the storage capacity of the compartments. The input and

TABLE 2

Storage (± S.D.), based on average standing crop, of different nutrients in grassland vegetation of the temperate zone of Western Himalaya

Plant Part	Nutrient		
	Nitrogen	Phosphorus	Potassium
		(g/m^2	
Aboveground photosynthetic	0.82 (± 0.59)	0.16 (± 0.11)	0.90 (± 0.75)
Standing dead	0.26 (± 0.24)	0.03 (± 0.03)	0.08 (± 0.05)
Litter	0.09 (± 0.07)	0.02 (± 0.02)	0.29 (± 0.02)
Belowground	0.83 (± 0.25)	0.11 (± 0.04)	0.47 (± 0.10)
Total	1.99 (± 0.38)	0.32 (± 0.07)	1.72 (± 0.29)

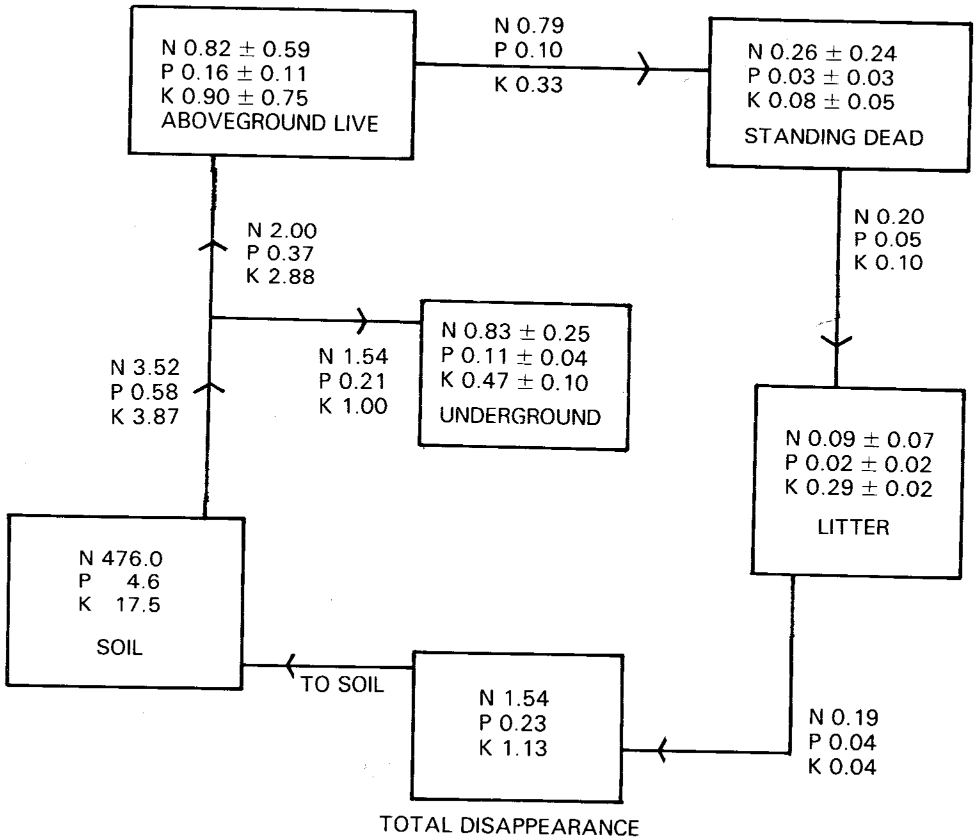

FIGURE 1

Net storage and transfer rates of nutrients (g/m^2/yr) in grassland vegetation of the temperate zone of Western Himalaya (Figures shown in rectangular boxes are the storage rate based on average standing crop of nutrients)

output of the 3 elements are those calculated from field data (Agrawal 1987). Net uptake is calculated from each nutrient equivalent and the net community production (Table 3). The latter values were estimated by summing up the positive species

TABLE 3

Total uptake and losses of various nutrients in temperate zone grassland vegetation of Western Himalaya

Compartment	Nutrient		
	Nitrogen	Phosphorus	Potassium
		($g/m^2/yr$)	
Soil level	476.00	4.60	17.50
Net uptake in:			
live compartment	1.98	0.37	2.88
standing-dead compartment	0.79	0.10	0.33
belowground compartment	1.54	0.21	1.00
litter compartment	0.20	0.05	0.10
Net loss from:			
litter	0.19	0.04	0.04
belowground	1.35	0.19	1.09
Total Net loss	1.54	0.23	1.13

increments in standing dead (until each of the constituent species reaches its peak aboveground live biomass) + positive increase in belowground biomass, throughout the study period. Outputs of net uptake of standing dead and litter, and losses from litter and belowground biomass were calculated using the method of Sims and Singh (1971) and Mall and Billore (1974).

Table 4 presents the annual uptake, retention and release of nitrogen, phosphorus and potassium. The difference between the uptake and release is assumed to be the amount of nutrient retained by the plant component. This data suggests that on an annual basis, potassium is the nutrient taken up in the greatest quantity (28.8 kg/ha/yr) followed by nitrogen (19.8 kg/ha/yr) and phosphorus (3.7 kg/ha/yr). Rate of release is higher for nitrogen (19.2 kg/ha/yr) than for potassium (6.3 kg/ha/yr) and phosphorus (1.5 kg/ha/yr). Consequently, potassium has the highest percentage of the 3 elements retained in plant parts (78.1%) followed by phosphorus (59.6%) and nitrogen (48.7%).

TABLE 4

Net uptake, release and retention of different plant nutrients in grassland vegetation of temperate Western Himalaya

Nutrient	Uptake		Release		Retention	
	(kg/ha/yr)	(%)	(kg/ha/yr)	(%)	(kg/ha/yr)	(%)
Nitrogen	19.79	(100)	10.15	(51.29)	9.64	(48.71)
Phosphorus	3.71	(100)	1.50	(40.43)	2.21	(59.57)
Potassium	28.76	(100)	6.31	(21.94)	22.45	(78.06)

The 4 plant components contain different concentrations of nitrogen, phosphorus and potassium. These 3 elements are highest in living tissue (aboveground live + belowground) and they decrease as the plant material degenerates to the litter stage. This decline may be due to weathering or to leaching by rain, or by translocation away from the dying tissue. The amount of potassium stored in live parts of the plants was higher than for nitrogen and phosphorus (Table 2). These differences may be attributed to their relative requirements in the metabolic processes, or to their relative availability in the ecosystem.

Nutrient levels recorded in the present study appear to be relatively low compared with those recorded in other grassland communities (Table 5). These values may reflect low nitrogen concentration in soil, and may also be the result of climatic factors, as edaphic factors are of prime importance in determining vegetation type, litter composition, humidity and the type of soil organism present (Witkamp and Van der Drift 1961).

TABLE 5

Annual uptake, release and retention of nutrients of different grassland vegetation of India (kg/ha)

Vegetation type	N	P	K	Author
Sehima grassland (Ratlam)				Billore and Singh (1976)
Uptake	58	16	18	
Retained	29	9	12	
Released	29	7	6	
Tropical grassland (Jhansi)				Trivedi and Misra (1983)
Uptake	83	10	—	
Retained	36	2	—	
Released	47	8	—	
Alpine grassland (Tungnath)				Sundriyal (1987)
Uptake	89	42	55	
Retained	18	13	29	
Released	71	29	26	
Present Investigation (Dwarikhal)				Agrawal
Uptake	20	4	29	
Retained	10	2	22	
Released	10	2	8	

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FORAGE SPECIES ADAPTATION TO RED EARTH SOILS IN SOUTHERN QUEENSLAND

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ABSTRACT

The adaptation of 52 legume and 77 grass accessions to red earth soils at 6 sites in southern Queensland was investigated by recording their persistence, spread and dry matter yield in fertilized and unfertilized plots over several years.

The best adapted species over all sites were in the legume genera Cassia *and* Stylosanthes, *and the grass genera* Digitaria *and* Urochloa.

Although there was a large yield response to applied fertilizer in the first year, it declined in the second year and was not detectable thereafter. The application of fertilizer had no effect on establishment, persistence or spread.

INTRODUCTION

Although a large suite of commercially available grass cultivars and several legume cultivars are adapted to the wetter areas of southern Queensland (annual rainfall > 750 mm), very few of these are adapted to drier regions. Despite work by O'Donnell *et al.* (1973) which showed the pasture potential of several grass species and 2 *Stylosanthes* species at Charleville, cultivars of buffel grass (*Cenchrus ciliaris*) comprise the major sown species on the more fertile soils of drier regions.

The drier region of southern Queensland is characterised by variable rainfall, length of pastoral growing season (both summer and winter), frost and drought incidence, and soils differing widely in physical and chemical attributes. As a first step in evaluating species for this region, we investigated the 'climatic' adaptation of a range of grass and legume accessions from similar homoclimes by growing them on red earth soils near Roma (26°35′S, 148°48′E), Charleville (26°25′S, 146°17′E), Blackall (24°25′S, 145°28′E), Longreach (23°27′S, 144°08′E) and Duaringa (23°42′S, 149°42′E).

This paper documents the persistence, mean maximum yield and spread of 52 legume and 77 grass accessions grown at each site.