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DISTRIBUTION AND CYCLING OF POTASSIUM IN SOIL-VEGETATION COMPONENTS OF SAND AND DUNE HERBACEOUS VEGETATION AROUND PILANI, RAJASTHAN, INDIA

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ABSTRACT

The distribution and cycling of potassium in the herbaceous vegetation were studied in sand and dune regions around Pilani (28°.23′N, 75°.37′E, elevation 350 m) at five sites from June, 1973 to May, 1974. Only 3-7% of the total soil potassium was involved in the biological circulation. Maximum uptake (3 g m^{-2}) of potassium occurred in interdunal lows during rainy season, out of which 83% was reflected in above ground live shoots and 17% in roots. The transfers were higher during winter. The maximum release of potassium through roots and litter decomposition occurred during winter season. On all the five sites, the total potassium annually absorbed by the vegetation ranged from 1.45 g m^{-2} to 3.35 g m^{-2}, 40-67% of it was returned to the soil through root and litter decomposition.

INTRODUCTION

Nutrient circulation and chemical changes in plants and soil are important in the study of ecosystem analysis. Mineral cycling through various components of the ecosystem can be used as a good indicator of the continuity and stability of any living system and thus is believed to be a useful strategy for ecosystem analysis (Pomeroy, 1970). Several factors affect the nutrient uptake, storage, transfer and release. The rate of uptake of nutrients as well as their release through litter and root decay and their further use depends upon the plant species, stage of maturity, rate of growth and the other environmental factors (William, 1964; Willard and Schuster, 1973). In any ecosystem, litter falling to the ground and root decomposition are normally regarded as the main routes by which nutrient circulation occurs.

In sand and dune ecosystems, micro-climate, soil, parent material, topography and biotic conditions as modified by time, produce most predictable pattern of

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nurient uptake. Potassium is highly mobile in the plant parts, for which the release rate from dead tissue is very slow (Billore and Mall, 1976). The present study was undertaken to assess the percentages and standing state of potassium (K) in different plant parts and in the soil, to determine the seasonal and annual uptake of K by plants from soil and to follow its transfer to various plant parts and its ultimate release to the soil.

MATERIAL AND METHODS

The study sites

Four sites, covering about 40 ha, were selected on unstabilized to semi-stabilized sand dune complex at Narhar (10 km from Pilani, 28°23′N and 75°37′E, elevation 350 m). The sites were located on the windward (Site I), top (Site II), leeward (Site III), and interdunal lows (Site IV) on the sand dune system. About 60-70% of the land was covered by sand dunes. Site V (excloxure) was located at Central Electronics and Engineering Research Institute (CEERI), Pilani and covered an area of 10 ha. The details of climate, vegetation, soil and primary production of these sites have already been reported by Singh and Joshi (1979, 1982, 1984, 1985 a).

The samples of above-ground (live) shoots, standing dead, litter and below ground (root) biomass in each of the five sites were collected from 10 quadrats (50 x 50 cm) chosen randomly at 15 days interval from June to September and at one month interval during the rest of the year. The samples were analysed for biomass estimations following Singh and Joshi (1984, 1985 b). The dried samples of the plant part from each of the five sites for each sampling date were ground to powder and used for K estimations. One of the material for each sampling date was digested by wet ashing procedure using nitric, perchloric and sulphuric acids and was analysed for K in Elico flame photometer. The soil samples from different sites were analyzed for K level in different months. Each time, a sample was drawn from three depths 0-5, 10-15 and 25-30 cm and then mixed thoroughly. This composite sample was analysed in triplicate by the method of Piper (1944).

The above-ground net production (ANP), standing dead production (SD), litter production (LP), litter disappearance (LD), below-ground net production (BNP), below-ground (root) disappearance (RD) and total disappearance (TD) values were calculated following Singh and Joshi (1984, 1985c). For nutrient uptake, transfer and release, the average seasonal values of K (mg g^{-}) for different plant compartments, viz., above-ground (live) shoots, standing dead, litter and below-ground biomass were multiplied by the seasonal values of ANP, SD, L, LD, BNP and RD to obtain the values for the components in terms of K (g m^{-2}) for each season. The annual values were obtained by summing the seasonal values.

RESULTS AND DISCUSSION

Potassium in different plant parts and in soil :

Potassium content in above-ground (live) shoots varied from site to site (Table 1). It was maximum at site I and minimum at site II. Sites II and III had low potassium content which may be attributed to greater run off at these sites. Potassium content ranged from 0.34% to 0.55% in dead shoots. The low potassium percentages (ranging from 0.37% to 54%) in litter as compared to above-ground (live) shoots and dead shoots may be due to the fast litter decomposition (Singh and Joshi, 1982) and mineralization. Slightly higher potassium content in litter compartment than in standing dead shoots at some of the sites resulted from freshly fallen leaves and branches of the herbaceous vegetation. The below-ground biomass had lower potassium content than above ground live shoots. Such findings have also been reported by White (1973) for prairie ecosystem. The soil contained very low percentage of potassium thorughout the year on all the sites (Table 1). Gill (1975) reported 0.0002-0.010% of potassium in the soils of Pilani, Rajasthan whereas in the present studies, a narrower range (0.004-0.006%) was there at the five sites. Billore and Mall (1976) recorded low values of 0.33%, 0.16%, 0.17%, 0.18% and 0.005% potassium for above-ground, standing dead, litter, below ground and soil, respectively, for the tropical *Sehima* grasslands at Ujjain (M. P.), India.

Table 1. Potassium (%) in different plant compartments and in soil over one year (June 1973 to May, 1974) in the five sites (Mean ± SE)

Site	Plant compartments				Soil*
	Above-ground (live) shoots	Standing dead shoots	Litter	Below-ground roots	
I (Windward)	1.13 ± 0.06	0.40 ± 0.06	0.37 ± 0.03	0.61 ± 0.04	0.005 ± 0.001
II (Top)	0.77 ± 0.03	0.34 ± 0.05	0.43 ± 0.02	0.53 ± 0.03	0.004 ± 0.001
III (Leeward)	0.80 ± 0.03	0.42± 0.08	0.48 ± 0.02	0.55 ± 0.02	0.004 ± 0.001
IV (Inter-dunal lows)	1.03 ± 0.07	0.46 ± 0.07	0.53 ± 0.02	0.67 ± 0.04	0.006 ± 0.001
V (Exclosure)	0.89 ± 0.06	0.55± 0.08	0.54 ± 0.03	0.69 ± 0.03	0.006 ± 0.001

*Depth 0 - 30 cm

The analysis of potassium content in different plant parts revealed significant differences due to sites in above-ground live shoots, litter, below-ground roots and in soil. The differences due to months in all the plant compartments and soil remained nonsignificant except for standing dead shoots. The sites X months interactions remained nonsignificant. However, the variability in above-ground (live) shoots (Table 2) was explained to the extent of 85% at site V and up to 12% at site I by the combination of mean monthly temperatare (°C) and rainfall (mm) while the percentage of potassium in below - ground parts varied less significantly with mean monthly

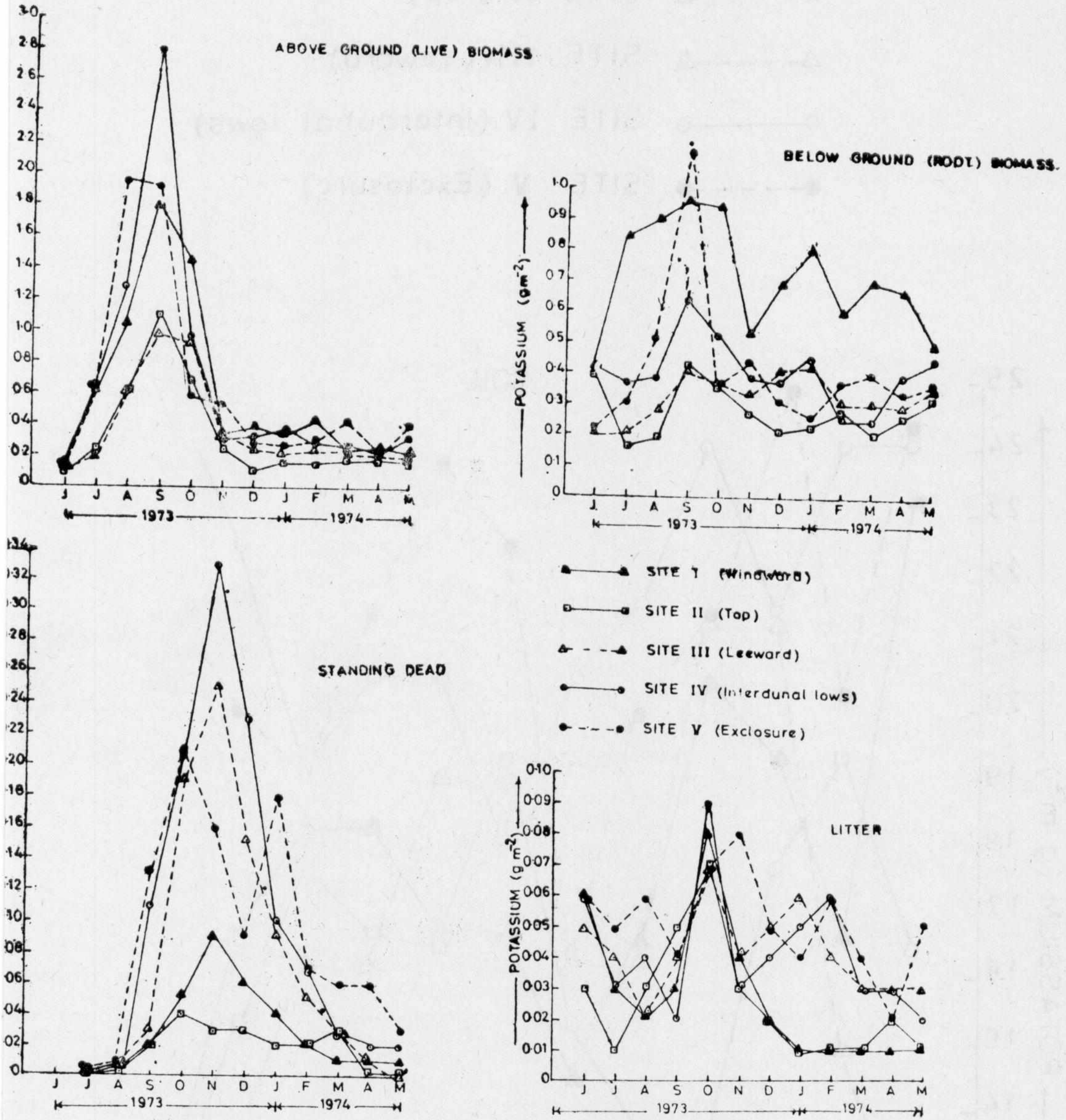
Table 2. Relationship between potassium (%), mean monthly temperature (X_1) and monthly rainfall (X_2) at the five sites for above-ground (live) shoots and below-ground plant parts.

Sites	Above - ground (live) shoots			Below - groundplant parts		
	Regression equation	R	SE	Regression equation	R	SE
I (Windward)	$Y=1.29+0.002X_1-0.009X_2$	0.34	0.42	$Y=0.48+0.000X_1+0.005X_2$	0.38	0.13
II (Top)	$Y=0.67+0.001X_1+0.003X_2$	0.56	0.08	$Y=0.38-0.001X_1+0.007X_2$	0.61	0.10
III (Leeward)	$Y=1\,01-0.001X_1-0.008X_2$	0.75	0.08	$Y=0.62+0\,000X_1-0.003X_2$	0.44	0.06
IV (Inter-dunal low)	$Y=1.02+0.002X_1-0.002X_2$	0.47	0.24	$Y=0.51-0\,001X_1+0.007X_2$	0.50	0.12
V (Exclosure)	$Y=0.83+0.003X_1-0.001X_2$	0.93	0.08	$Y=0.63+0.001X_1+0.002X_2$	0.33	0.11

temperature and rainfall. It showed maximum (37%) variability at site II and minimum (11%) at site V. The phenological changes in the vegetation and dilution effect of rainfall on the growth of plants complicate the relationships and, therefore, only a part of the variability is explained by these factors.

Standing state of potassium in plant parts and soil :

The standing state (g m^{-2}) of potassium in above ground (live) shoots at all the five sites reached a peak during the rainy season. All the sites exhibited a contant increase in the amount of potassium in above-ground (live) shoots from June to September, which corresponded to the increase in the standing crop of above-ground (live) shoots (Fig. 1). There was regular decline after September in the standing state until December/January on all the sites when maturity and death of the rainy season vegetation normally occurred. The higher values in winter and summer seasons resulted partly from the greater biomass of perennials with higher potassium content. The amount of potassium in dead shoots was 0.33 g m^{-2} in November at all the sites. The amount (g m^{-2}) of potassium in litter fluctuated between sites and months. The little amount during summer can be accounted for by accelerated decomposition or removal of litter from these sites by wind action. The standing state (g m^{-2}) of potasium in roots and all the sites reached a maximum during rainy season and declined after September till January. In general, the amount of potassium was higher in above-ground (live) shoots as compared to the roots in all the seasons which indicated that the potassium accumulation is directed above-ground. In the present study, the maximum standing state in vegetation for K amounted to 3.35 kg ha^{-1}. The soil had no definite trend for the amount of potassium (Fig. 2). However, it ranged from 12 33 g m^{-2} (summer season) on site II to 24.45 g m^{-2} (rainy season) on site V. Egunjobi (1971) reported quite high amount (550 kg ha^{-1}) of K in the top 28 cm of soil in a stand of *Ulex europaeus* whereas Robertson and Davis (1965) reported 178 kg ha^{-1} of K, in a heather ecosystem.



G.1, STANDING STATE (g m^{-2}) OF POTASSIUM IN DIFFERENT PLANT COMPARTMENTS IN DIFFERENT MONTHS AT FIVE STUDY SITES

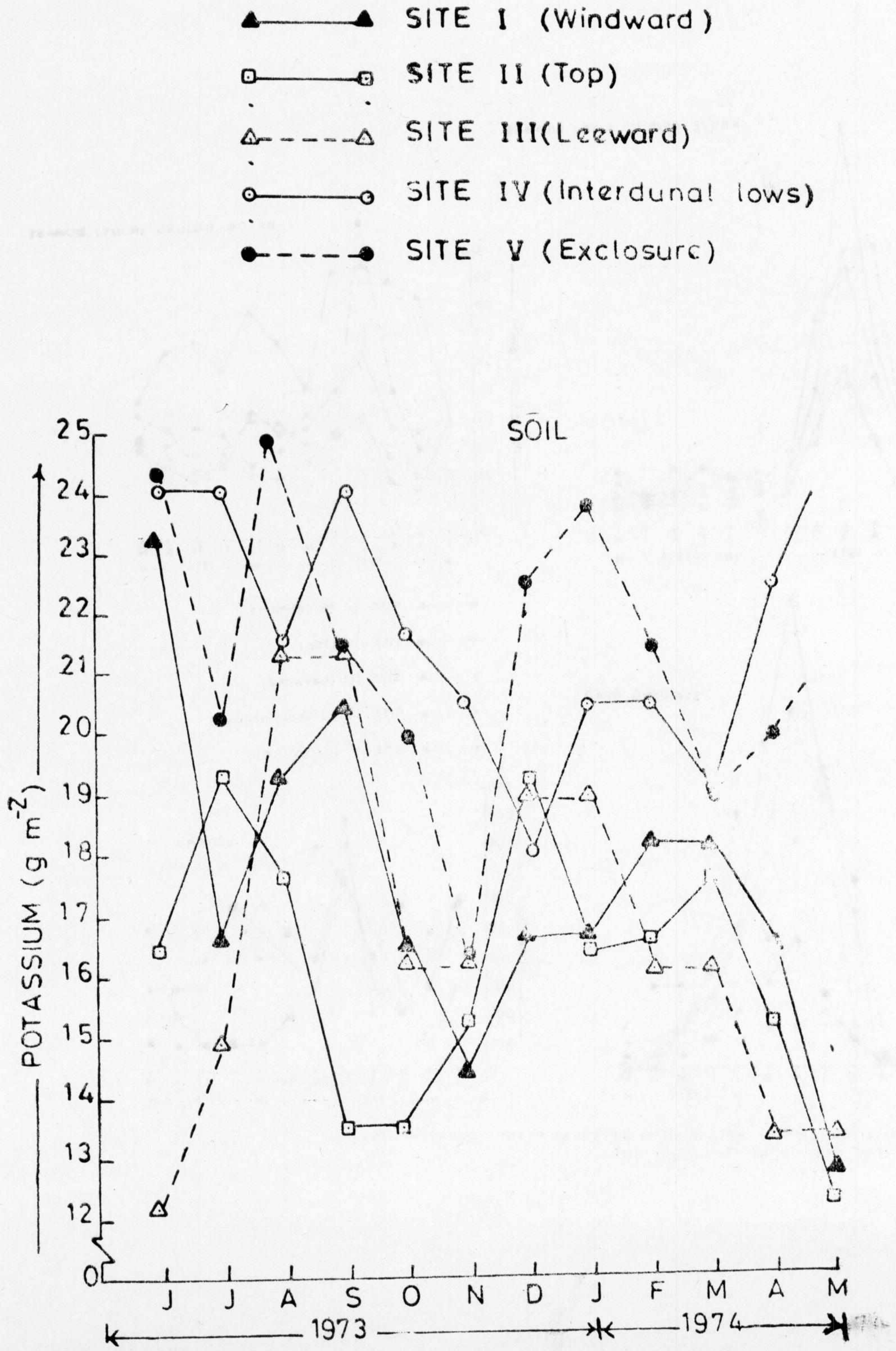


Fig. 2. Standing state (g m^{-2}) of potassium in soil in different months at five study sites.

Analysis of variance for the standing state of potassium in different plant parts and soil for different sites, months and site X months interactions indicated significantly different amount of potassium in above-ground (live shoots and in soil due to sites). The differences due to month were highly significant in above-ground (live) shoots and below-ground plant parts. The site X month interactions were non-significant. The site X month X compartments was highly significant which indicated that the components behaved differently on different sites in different months.

The standing state (g m^{-2}) of potassium in above-ground (live shoots) and below-ground (roots) had little relationships with monthly temperature and rainfall (Table 3). Rainfall and temperature had, thus, very little effect on the storage of potassium in below-ground roots but favoured accumulation of potassium in above-ground shoots.

Table 3. Relationship between potassium (g m^{-2}), mean monthly temperature (X_1) and rainfall (X_2) at the five sites for above - ground (live) shoots and below - ground plant parts

Sites	Above-ground (live) shoots			Below-ground plants parts		
	Regression equation	R	SE	Regression equation	R	SE
I (Windward)	$Y=0.50+0.003X_1-0.001X_2$	0.43	0.54	$Y=0.82-0.002X_1-0.004X_2$	0.59	0.22
II (Top)	$Y=0.22+0.002X_1+0.001X_2$	0.48	0.30	$Y=0.18-0.001X_1+0.005X_2$	0.55	0.08
III (Leeward)	$Y=0.38+0.002X_1-0.002X_2$	0.36	0.30	$Y=0.45-0.000X_1-0.005X_2$	0.65	0.06
IV (Inter-dun al low)	$Y=0.44+0.005X_1+0.003X_2$	0.49	0.72	$Y=0.32+0.000X_1+0.004X_2$	0.33	0.11
V(Exclosure)	$Y=0.43+0.008X_1-0.002X_2$	0.82	0.40	$Y=0.38+0.001X_1-0.000X_2$	0.37	0.21

Seasonal distribution of potassium in the plant–soil system :

Only 3–7% of the total potassium circulated in the biological components of the vegetation over one year period on all the sites. The potassium in the above-ground (live shoot) ranged from 2.91% to 4.45% and in roots from 1.09% to 2.15% during rainy season. It was negligible in standing dead shoots and litter. During winter, standing dead and litter retained appreciable amounts in their biomass (Table 4) In the summer, soil retained about 97% of the total reserves of potassium. The proportion of potassium in below-ground parts as compared to live shoots was low in the summer which indicated that potassium remained more in above-ground (live shoots) throughout the season. Annually, the potassium was directed above-ground.

The pattern of per cent distribution of K in different compartments differed significantly for the different sites, seasons and also for the site X season interaction. This indicated differential response of the plant compartments in different sites and seasons.

Table 4. Seasonal and annual distribution patterns (%) of potassium in soil-plant system at the five sites

Sites	Plant compartments				Soil
	Above-ground (live)	Standing dead	Litter	Roots	
		Rainy Season			
I (Windward)	4.44	0.09	0.15	2.15	93.17
II (Top)	2.91	0.12	0.17	1.09	95.71
III (Leeward)	3.12	0.05	0.22	1.48	95.13
IV (Inter-dunal lows)	4.45	0.12	0.16	1.87	94.30
V (Exclosure)	3.54	0.17	0.21	2.01	94.07
		Winter Season			
I (Windward)	3.39	0.79	0.17	2.43	93.22
II (Top)	1.55	0.47	0.17	1.94	95.87
III (Leeward)	1.72	0.72	0.27	2.05	95.24
IV (Inter-dunal lows)	2.25	0.84	0.25	1.87	94.79
V (Exclosure)	1.88	0.69	0.28	1.51	95.64
		Summer Season			
I (Windward)	1.65	0.25	0.04	1.65	96.41
II (Top)	1.16	0.07	0.07	1.67	97.03
III (Leeward)	1.42	0.07	0.14	2.17	96.20
IV (Inter-dunal lows)	1.20	0.09	0.21	1.58	96.92
V (Exclosure)	1.53	0.24	0.19	1.77	96.27
		Annual			
I (Windward)	3.23	0.44	0.16	1.94	94.23
II (Top)	1.90	0.24	0.12	1.61	96.13
III (Leeward)	2.14	0.35	0.23	1.90	95.83
IV (Inter-dunal lows)	2.65	0.30	0.21	1.78	95.06
V (Exclosure)	2.63	0.40	0.22	1.74	95.01

Seasonal uptake, transfers and release of potassium :

The total annual uptake of potassium was maximum on site IV and minimum on site II during rainy season (Table 5), a major portion reflected in the above-ground (live shoots). The transfer of potassium from live shoots to dead shoots was very poor, and the transfer from dead shoots to litter was nil during rainy season on all the sites. The total release of potassium was mainly through root decomposition. Of the total uptake, 1.96%, 4.65%, 4.44%, 2.67% and 2.99% of the potassium was released to the soil during the rainy season in sites I-V respectively. The uptake decreased considerably during the winter. The potassium distribution to below-ground roots, however, was higher during this season. The transfer of potassium from above-ground (live shoots) to standing dead shoots and later to litter was maximum during the winter season. At the site V, the rate of transfer of potassium from dead shoots to litter was rapid and equal to its rate of release from the litter during the winter season. The release through roots was low compared to the release from litter. In winter, return of K to soil was 4.89, 8.89, 11.83 6.14 and 14.18 times that of the total

Table 5. Annual uptake, transfer and release of potasium (g m^{-2}) in the five study sites (I to V)

* State of potassium	Rainy season					Winter season					Summer season				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Uptake in ANP	2.07	1.15	1.17	2.48	1.75	0.08	0.04	0.01	0.12	0 03	0.12	0.04	0.09	0.04	0.19
Uptake in BNP	0.28	0.14	0.18	0.52	0.59	0.10	0 05	0.05	0.09	0.08	0.10	0.03	0.03	0.10	0.08
Total uptake	2.35	1.29	1.35	3.00	2.34	0.18	0.09	0.06	0.21	0.11	0.22	0.07	0.12	0.14	0.27
Transfer from ANP to SD	0.08	0.07	0.03	0.11	0.14	0.58	0.47	0.70	1.02	1.09	0.05	0.01	0.05	0.01	0.20
Transfer from SD to litter	0.00	0.00	0.00	0.00	0.00	0.47	0.62	0.59	0 90	1.08	0.07	0.04	0.09	0.07	0.14
Release from litter	0.02	0.02	0.01	0.06	0.06	0.50	0.64	0.59	0.86	1.08	0.08	0.04	0.12	0.08	0.13
Release from root	0.03	0.04	0.05	0.02	0.01	0.38	0.16	0.12	0.43	0.48	0.08	0.03	0.04	0.11	0.07
Total release	0.05	0.06	0.06	0.08	0.07	0.88	0.80	0.71	1.29	1.56	0.16	0.07	0.16	0.19	0.20
K in soil±	19.93	16.75	17.39	23.49	22.85	16.49	16.28	17.21	20.23	20.87	15.87	15.07	14.21	22.68	20.16

*ANP = Above-ground net production, BNP=Below-ground net production SD=Standing dead vegetation.
± = K μg/g × Bulk density.

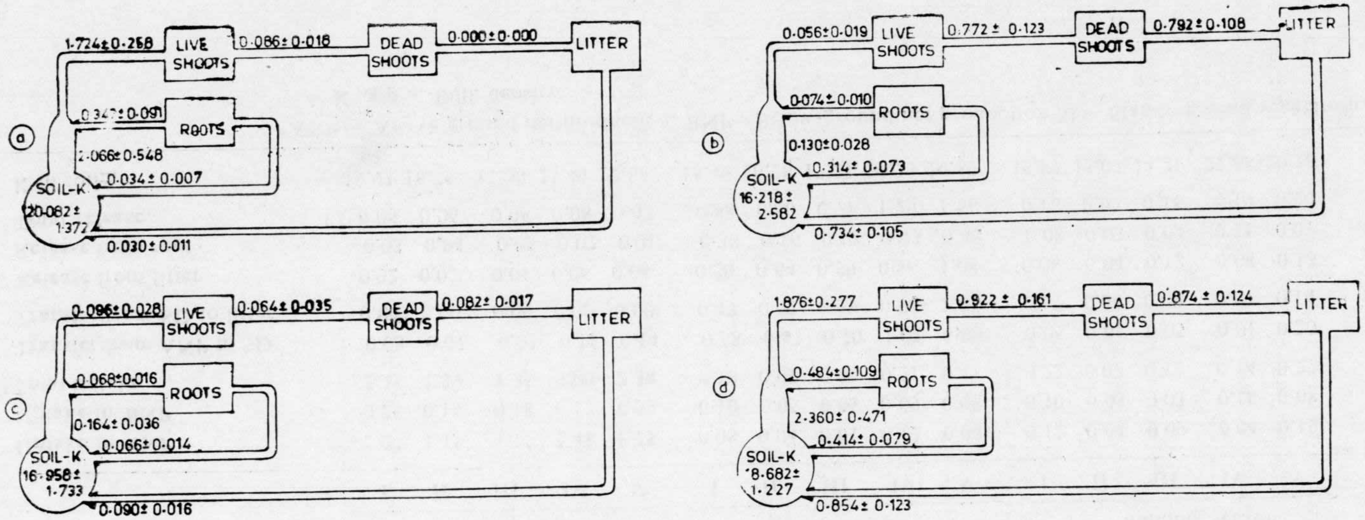


Fig. 3. CYCLING OF POTASSIUM IN SOIL-VEGETATION COMPONENTS OF SAND AND DUNE REGIONS AROUND PILANI, INDIA FROM JUNE 1973 TO MAY 1974. (a) RAINY SEASON (122 DAYS, TOTAL K-RELEASE, 0·064±0·005), (b) WINTER SEASON (151 DAYS, TOTAL K-RELEASE, 1·048±0·162), (c) SUMMER SEASON (91 DAYS, TOTAL K-RELEASE, 0·156±0·023) AND (d) ANNUAL (365 DAYS, TOTAL K-RELEASE, 1·268±0·182). VALUES ON THE ARROWS ARE TRANSFERS OF POTASSIUM IN GRAMS PER SQUARE METRE ±1 SE (AVERAGED FROM ALL THE FIVE SITES).

Table 3. Effect of spacing and levels of phosphorus on the dry matter yield (q/ha) of *Dichanthium annulatum* and *Sesbania sesban.*

Treatments	1983			1984			Mean		
	Grass	Legume	Total	Grass	Legume	Total	Grass	Legume	Total
Spacing (cm)									
50	40.2	29.8	70.0	55.8	6.0	61.8	48.0	17.9	65.9
75	41.5	25.7	67.2	51.1	8.9	60.0	46.3	17.3	63.6
100	37.8	26.1	63.9	48.9	6.7	55.6	43.3	16.4	59.7
SEm ±	2.0	1.9	4.5	4.2	1.9	5.9	—	—	—
CD at 5%	NS	NS	NS	NS	NS	NS	—	—	—
Levels of P_2O_5 (kg/ha)									
0	38.0	25.3	63.3	49.7	5.5	55.2	43.8	15.4	59.2
30	42.3	28.4	70.7	52.5	7.9	60.4	47.4	18.1	65.5
60	39.2	28.0	67.2	53.5	8.3	61.8	46.3	18.0	64.4
SEm ±	2.0	1.9	4.5	4.2	1.9	5.9	—	—	—
CD at 5%	NS	NS	NS	NS	NS	—	—	—	—

Table 2. Effect of spacing and levels of phosphorus on crude protein yield (q/ha) of *Dichanthium annulatum* and *Sesbania sesban*

Treatment	1983			1984			Mean		
	Grass	Legume	Total	Grass	Legume	Total	Grass	Legume	Total
Spacing (cm)									
50	2.8	6.3	9.1	3.5	1.2	4.7	3.2	3.8	6.9
75	2.8	5.1	7.9	3.1	1.8	4.9	2.9	3.5	5.4
100	2.6	5.5	8·1	3.0	1.4	4.4	2.8	3.5	6.2
SEm—±	0.13	0.23	0.15	0.26	0.36	0.41			
CD at 5%	NS	0.69	NS	NS	NS	NS			
Levels of P_2O_5 (kg/ha)									
0	2.5	5.1	7.6	3.0	1.1	4.1	2.8	3.1	5.9
30	2.9	5.9	8.8	3.3	1.7	5.0	3.1	3.8	6.9
60	2.7	5.9	8.6	3.3	1.7	5.0	3.0	3.8	6.8
SEm– ±	0.13	0.23	0.51	0.26	0.36	0.41	—	—	—
CD at 5%	NS	NS	NS	NS	NS	NS	—	—	—

though vigorous, could not compensate for forage yield. Application of phosphorus gave higher forage yield in both the years. However, the effect was not significant on the forage yield either of grass or of legume as well as on total yield of grass + legume during both the years (Table 2). Average production of the years revealed that application of 30 kg P_2O_5/ ha was more beneficial (65.5 q/ha) than 60 kg P_2O_5/ha (64.4 q/ha).

S. sesban could not withstand frequent cutting system in this type of soil under rainfed conditions, as there was mortality in the subsequent year of 1984. This resulted in higher average yield of grass in 1984 than in 1983. The results suggest that *S. sesban* would need to be resown every year for intercropping with *D. annulatum.*

Crude protein yield :

There were no significant differences in crude protein yield of either grass or legume as well as total of grass + legume due to different spacings during both the years except legume yield of 1983. However, average yield of two years showed comparatively higher yield at 50 cm spacing as compared to 75 and 100 cm. Due to application of phosphorus significant variation in crude protein yield was not observed in both the years. However, application of phosphorus gave higher crude protein yield than control because of higher dry matter yield and higher per cent crude protein in both the components. Due to appplication of phosphorus, the crude protein content of grass as well as legume comparatively increased during both the years than control. Further, it was observed that there was no beneficial effect of 60 kg P_2O_5/ha over 30 kg P_2O_5/ha on crude protein yield as well as crude protein content.

Metabolizable energy :

Data in table 4 showed nonsignificant differences in metabolizable energy of grass, legume and total of grass + legume due to different spacings and levels of phosphorus during both the years. However, the total metabolizable energy obtained with grass + legume during 1983 and 1984 was higher with 50 cm spacing as compared to 75 and 100 cm. Average of two years revealed that 50 cm spacing gave 3.6 and 10.2 per cent higher metabolizable energy over that of 75 and 100 cm. Due to application of 30 and 60 kg P_2O_5/ha also the metabolizable energy increased by 11.2 and 9.5 per cent respectively over control.

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Table 4. Effect of spacing and phosphorus on metabolizable energy (M cal/ha) in *Dichanthium annulatum* and *Sesbania sesban*

Treatment	1983			1984			Mean		
	Grass	Legum	Total	Grass	Legume	Total	Grass	Legume	Total
Spacings (cm)									
50	5909	5692	10601	8202	1148	9348	7053	3419	10472
75	6100	4908	11008	7512	1699	9211	6805	3303	10108
100	5556	4985	10541	7188	1280	8468	6372	3132	9504
SEm ±	278	396	540	626	357	671			
	ns	ns	ns	ns	ns	ns			
Levels of $P_2 0_5$ (kg/ha)									
0	5586	4832	10418	7305	1050	8355	6445	2941	9386
30	6218	5424	11642	7717	1509	9226	6967	3466	10433
60	5762	5348	11110	7864	1585	9449	6813	3466	10279
SEm ±	278	396	540	626	357	671			
	ns	ns	ns	ns	ns	ns			

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