Proc. Indian natn. Sci. Acad.
Vol. 42, Part B. Nos. 2 & 3, pp. 89–101.
Plant Ecology

SHORT-TERM EFFECT OF BURNING ON THE STANDING CROP AND CYCLING OF PHOSPHORUS IN SOIL-VEGETATION COMPONENTS OF *DICHANTHIUM ANNULATUM* STANDS AT VARANASI

by A. N. PANDEY, *Botany Department, Banaras Hindu University, Varanasi* 221 005
(Communicated by R. MISRA, FNA)
(*Received* 19 *April,* 1976)

The paper presents the distribution of phosphorus in different plant compartments and in the top 30 cm soil of *Dichanthium annulatum* grassland during the year 1970 which was protected for about three years at Varanasi. Partitioning, uptake, transfer and release of phosphorus in the aboveground and underground compartments were computed for all the three plots. The burnt plots indicated greater concentration of phosphorus in the soil, above-ground and underground plant tissues as compared to the control plot. The major portion of phosphorus (96.29% in the first plot, 96.53% in the second plot and 96.60% in the third plot) in the system is retained in the soil while a fraction of phosphorus (3.71% in the first plot, 3.47% in the second plot and 3.40% in the third plot) is found in the biological material. Hence, the present investigation indicates that burning improves the phosphorus economy of the system as well as enhances its circulation within the system.

INTRODUCTION

The climate of India, largely, has the potentiality foı the development of forest ecosystems whereas fire and grazing check the regeneration of trees and help in maintenance of savanna vegetation. Of course there are a number of works on the effect of grazing in the grasslands but 'fire' as an ecological factor has not been studied specially in India. Hence, in order to understand the effect of fire in the ecology of grasslands a need of an extensive work was felt. The author woıked on grassplots with controlled 'fiıe' at the Banaras Hindu Univeısity. An account of the short-term effect of burning on the vegetation composition, primary productivity and nitrogen cycling in the *Dichanthium annulatum* stands at Varanasi was given earlier (Pandey 1974, 1976). This papeı deals with the effect of experimental burning on (i) the standing crop and the distribution of phosphorus in different components of regrowth of the producer subsystem, viz., above-ground crop, litter, root and rhizome, and soil throughout the year, and (ii) the annual uptake of phosphorus fıom soil, its transfer to various above-ground plant components, and its ultimate release to soil.

THE STUDY SITE

The study site is situated in the Botanical Garden of the Banaras Hindu University. It is located in the Upper Gangetic plains near the west bank of the Ganges river in the southern end of Varanasi city. The ground is level and the mean height from the sea level is approximately 76.19 m. Geographically the area is subtropical but hot summers modulated by monsoon and short winter give it a tropical character. The year is conveniently divided into three distinct seasons viz., winter (November to February), Summer (March to June) and rainy season (mid June to early October). The mean maximum temperatuie ranges from 23.75°C in January to 42.97°C in May, and the mean minimum temperature is 28.11°C in May and 9.25°C in Decembei. Relative humidity ranges from 63.77 to 93.09% foi the whole year at 8 AM. Total annual rainfall duiing the year 1970 was 759.80 mm, of which 86.4% occurred in the rainy season.

MATERIALS AND METHODS

(a) *Burning*—For carrying out the artificial burning, the site was divided into three equal subplots numbered I, II and III. Four permanent quadrats of 1 m × 1 m size were marked with nails at random in each subplot. An area 2 m wide, around each quadrat was left intact. The vegetation around the intact area was denuded by scraping for 1 m width. An iron rod was wrapped with cloth and soaked in kerosene oil. This was lit and with the help of its flame, quadiats with suirounding vegetation of 2 m were burnt in the I and II plots on 30th January, 1970. Fire was set at one or two places at the margin which spread over the ground surface since the vegetation was nearly diy and it consumed all the standing crop. Unburnt plot III served as control. The I plot was again burnt on 30th of May in the same way. It was not possible to measuie the intensity of fire. The ash iemained mostly stuck on the tough giound due to protection offered by the surrounding vegetation and light shower within a few days of the burns. Regeneration of the herbage occurred from underground parts following the burn.

(b) *Sampling*—The samples of aboveground and underground standing crop for the chemical analysis, were taken from the 2 m area around the quadrats in each month from each subplot and were oven-dried at 80°C. Soil samples foi the three different depths, i.e., 0–10 cm, 10–20 cm and 20–30 cm were also collected from the same 2 m area in each month for all the three subplots. The soil was air-dried and root segments were removed mechanically.

(c) *Chemical analysis*—(i) The soil analysis was made by colorimetric method foi total phosphorus by the method described by jackson (1958). The phosphorus content in per gram dry weight of soil was multiplied with the bulk density and the result is expressed as g/m^2 of phosphorus. (ii) The total plant phosphorus was also determined by colorimetric method as given by Jackson (1958), and the phosphoius content for 1 m^2 herbage was computed from its biomass.

Phosphorus uptake, transfer and release

The annual net production of phosphorus for the different plant components is estimated by summing up all the positive increments in the phosphorus contents of the different months. A sum of the annual net production for all the plant components yields the estimate of total annual uptake by plants. The annual net production of phosphorus in litter is considered for the transfer value from the shoot. The release of phosphorus is calculated as follows:

Rh.D. = Initial weight of rhizome biomass + Annual net production of rhizome − Final weight of rhizome biomass

R.D. = Initial weight of root biomass + Annual net production of root − Final weight of root biomass

L.D. = Initial weight of litter + Litter production − Final weight of litter

The L.D., Rh.D. and R.D. values, when multiplied with annual mean value of phosphorus in per gram biomass of litter, rhizome and root respectively, yield the estimates of the release of phosphorus into the system through litter, rhizome, and root.

RESULTS

Distribution of phosphorus in various soil vegetation components

Soil-phosphorus—The concentration of phosphorus in the soil at each depth for all the three plots varies during different months and seasons. The first burning on 30th January causes 27.8 % and 27.11 % increase in the amount of phosphorus at the surface soil in the I and II plots respectively as compared with the figures of the control plot during February as given in Table I. The lower depths remain unaffected. Thereafter, on 19th and 20th February, a heavy rainfall is recorded which brings an increase in soil phosphorus at each depth of all the three plots. As the summer season advances, phosphorus content at each depth of soil gradually decreases till June in all the three plots. The decrease in soil phosphorus in the I plot at surface of the soil is less since the second burning in May brings 21.5 % increase in phosphorus as compaedr to the pre-existing amount in May. Beyond summer an increase in the amount of phosphorus is observed in rainy season and it peaks in August at all the three depths of the control as well as the burnt plots which is followed by a gradual decrease during the winter. The annual increase of phosphorus at all the depths for all the three plots follows a decreasing trend with increasing depth. The total annual increment for the 0–30 cm depth is 133.514 g/m^2, 96.161 g/m^2 and 71.424 g/m^2 in the I, II and III plots respectively.

Standing state of phosphorus in the plant components

(i) *Shoot*—The amount of phosphorus increases by 20.8 % in the control plot during March as compared to the January figure. Thereafter, it follows a steady decrease till June as shown in Table II, whereas the burnt plots show 52.7 % decrease in the amount of phosphorus in March as compared to the control plot and it goes on decreasing till June. Further, in the I plot 80 % decrease in the amount of phosphorus is obtained after the second burning as compared to the pre-existing amount of phosphorus in May. With the onset of rain a marked increase in the amount of phosphorus is obtained in the control as well as in the burnt plots. The burnt plots show a higher rate of increase than that of the control plot. Maximum value is obtained in August for the II and III plots and during August and September for the I plot. It is followed by a decrease till November. Further increase in the amount of phosphorus is observed in December in each plot. However, the total amount of phosphorus is always less in the burnt plots as compared to that of the control plot but the I plot shows a slight increase of phosphorus from October to December only.

(ii) *Rhizome*—The phosphorus content of rhizome decreases during March in the control as well as in the burnt plots but the latter show less decrease as given in Table II. A gradual increase in the amount of phosphorus is obtained from May to August in the II and III plots whereas the second burning decreases the amount of phosphorus in the I plot during June. It increases in July but does not reach the values of the other two plots. This increase is followed by a steady decrease till October. Further, an increase in the amount of phosphorus is recorded in November and December in each plot. However, the II and the III plots have more or less equal values throughout the year whereas the value of the I plot is low.

(iii) *Root*—The amount of phosphorus increases in the control plot during March which is followed by a decrease in summer till June as presented in Table II. It decreases after the first burning till June in the II plot and till May in the I plot. During the rainy season the amount of phosphorus increases in the control as well as in the burnt plots till it reaches the maximum value in August. However, the peak values of the II and the III plots are nearly the same but the value of the I plot is quite high in comparison to those of the II and III plots. The maximum value is followed by a steady decrease in the amount of phosphorus onwards but the I plot shows an increase in the phosphorus content in December.

(iv) *Litter*—The value of phosphorus is greater in summer in the control plot and during winter in the burnt plots as given in Table II. The quantity of phosphorus increases from March to June in the II and III plots whereas it is nil in the I plot after the second burning. A short decrease in the amount of phosphorus is obtained during July in each plot. Beyond July a continuous increase in the quantity of phosphorus is found.

Amount of phosphorus stored in total standing crop

The data as set in Table II show similar trend of fluctuation as found in phosphorus content of shoot. The amount of phosphorus in total standing crop increases during March in the control plot which is followed by a gradual decrease till June. The burning causes a decrease in phosphorus content till June in the I and II plots. Minimum values for phosphorus content as obtained in June are 0.58 g/m², 1.12 g/m² and 1.97 g/m² in the I, II and III plots respectively. During rainy season a marked increase in phosphorus content is recorded in the control as well as in the burnt plots which is followed by a short decrease in October and November. Further increase in the amount of phosphorus is observed in December. Maximum values are 4.29 g/m² in the I plot and 3.89 g/m² in the II plot during December and 4.60 g/m² in the III plot during August. The amount of phosphorus is always slightly less in the II plot in comparison to the III plot. The value in the I plot is less till the rainy season and it becomes more or less equal to the value of the control plot in winter.

Fluctuation in concentration of phosphorus of burnt plots as compared to the control plot in relation to biomass of Dichanthium annulatum

The percentage decrease in the shoot biomass of the burnt plots is more as compared to phosphorus content as given in Table III. The differences for the standing crop and phosphorus content of shoot persist throughout the year but are gradually minimized till

TABLE I

Monthly variation in concentration of soil phosphorus (g/m^2) *of three experimental plots of* Dichanthium annulatum *grassland at different depths*

Months	0–10 cm			10–20 cm			20–30 cm		
	I Plot	II Plot	III Plot	I Plot	II Plot	III Plot	I Plot	II Plot	III Plot
January			63.222±3.24			35.110±2.1			19.435±1.2
February	81.263±2.6	80.955±1.8	63.530±2.8	35.110±1.6	35.110±1.6	35.110±1.8	19.435±1.0	19.435±0.87	19.435±1.0
March	84.193±3.7	84.039±1.4	65.535±3.8	37.811±3.3	37.980±3.7	37.136±3.3	20.956±1.4	21.125±1.6	20.280±1.3
April	68.773±4.3	68.927±3.2	50.115±2.3	35.448±2.4	35.448±3.1	33.760±1.6	19.435±1.1	19.435±1.1	18.590±1.1
May	56.437±3.0	56.283±3.1	37.933±3.5	27.345±3.4	27.008±1.6	25.320±2.3	12.675±1.0	12.506±0.84	11.830±0.84
June	68.629±1.5	56.128±3.4	37.933±3.7	27.008±1.9	27.008±1.4	25.320±3.5	12.675±1.1	12.675±1.0	11.830±0.87
July	105.627±3.6	87.123±2.7	69.390±5.2	48.108±3.3	41.356±2.5	38.824±2.5	38.025±2.1	32.110±1.6	24.505±1.9
August	109.482±4.0	87.894±4.0	71.240±1.1	51.484±2.1	44.732±2.8	41.356±2.7	40.560±2.3	33.800±2.0	26.195±1.8
September	105.627±2.9	85.581±2.3	67.848±2.9	48.108±2.7	41.356±2.2	37.980±2.1	35.490±1.8	27.885±1.6	23.153±1.8
October	102.543±2.5	81.726±1.2	65.535±4.7	40.863±3.8	38.824±2.3	33.760±4.4	33.800±1.6	26.195±1.3	21.125±1.3
November	101.772±3.0	79.413±3.6	63.993±2.5	43.888±2.8	37.980±2.0	36.292±2.0	32.955±1.5	24.505±1.2	18.590±0.85
December	101.001±3.2	78.950±3.1	63.993±2.9	43.888±2.6	37.980±2.4	36.292±2.5	32.955±1.6	24.505±1.2	18.590±1.1
Annual increment	74.016	52.583	35.620	30.192	20.594	20.594	29.306	22.984	15.210

I Plot—twice burnt in January and May, 1970
II Plot—once burnt in January, 1970
III Plot—unburnt (control)

TABLE II

Biomass fractions (g/m^2) of Dichanthium annulatum *and their phosphorus concentrations (g/m^{-2}) for the three experimental plots during different months of the year* 1970

Months	Plant Compo-nents	I Plot		II Plot		III Plot	
		Biomass	Phosphorus	Biomass	Phosphorus	Biomass	Phosphorus
Jan.	Shoot					1455.0±47.5	1.82±0.05
	Rhizome					493.5±14.9	0.48±0.01
	Root					217.5±28.8	0.03±0.007
	Litter					40.0	0.0234
	Total					2206.0	2.35
March	Shoot	628.3± 6.3	1.04±0.01	627.5± 9.0	1.04±0.02	1582.5±53.4	2.20±0.06
	Rhizome	411.6±11.8	0.46±0.01	410.0±15.0	0.47±0.01	442.5±13.9	0.45+0.08
	Root	123.3±25.1	0.02±0.01	120.0±30.0	0.02±0.01	200.0+25.0	0.04±0
	Litter	10.3	0.0079	14.0	0.0108	32.0	0.0144
	Total	1173.5	1.52	1171.5	1.54	2267.0	2.70
May	Shoot	458.3± 7.6	0.70±0.01	459.0±13.8	0.70±0.01	1250.0±62.4	1.57±0.06
	Rhizome	486.6±16.2	0.51±0.01	485.0±18.0	0.51±0.01	524.5±24.3	0.51±0.02
	Root	98.4±10.5	0.01±0.007	100.0±10.0	0.01±0.007	177.5±9.0	0.02±0.007
	Litter	83.2	0.0644	80.0	0.0640	205.0	0.1127
	Total	1126.5	1.28	1124.0	1.28	2157.0	2.21
June	Shoot	82.5± 2.5	0.14±0	360.0±13.9	0.51±0.02	1130.0±21.3	1.32±0.05
	Rhizome	432.5±17.5	0.43±0.02	535.5±12.7	0.53±0.01	564.25±11.8	0.52±0.007
	Root	75.0±26.3	0.012±0.005	95.0± 9.0	0.01±0	170.0±11.4	0.02±0
	Litter	x	x	98.0	0.0735	235.0	0.1116
	Total	590.0	0.58	1088.0	1.12	2089.0	1.97
July	Shoot	740.0±16.3	1.62±0.01	960.0±23.8	1.86±0.05	1607.5±77.0	2.77±0.11
	Rhizome	382.0±22.1	0.50±0.02	492.0±15.8	0.61±0.02	525.0± 9.0	0.61±0.01
	Root	177.5±20.4	0.06±0.007	175.0±25.0	0.05±0.01	252.5±19.8	0.05±0.01
	Litter	x	x	10.0	0.0041	25.0	0.0006
	Total	1299.0	2.18	1663.0	2.52	2410.0	3.43
Aug.	Shoot	1480.0±40.6	3.61±0.03	1607.5±49.1	3.33±0.11	2167.5±117.8	3.90±0.24
	Rhizome	322.0±37.5	0.49±0.05	444.5±27.0	0.61±0.03	482.5±22.9	0.61±0.01
	Root	250.0±25.0	0.12±0.01	245.0±26.4	0.01±0.01	255.0±18.8	0.01±0.01
	Litter	2.0	0.0033	4.5	0.0061	10.0	0.0107
	Total	2054.0	4.22	2301.5	4.02	2915.0	4.60
Sept.	Shoot	1593.0±08.4	3.61±0.04	1707.5±24.1	3.22±0.03	2232.5±48.2	3.72±0.12
	Rhizome	313.0±10.4	0.43±0.01	435.0±27.0	0.54±0.03	475.0±10.0	0.54±0.01
	Root	254.0±31.3	0.09±0.01	250.0±37.6	0.07±0.01	262.5±11.4	0.06±0
	Litter	50.0	0.0718	55.0	0.0625	75.0	0.0768
	Total	2210.0	4.20	2248.0	3.89	3045.0	4.39

TABLE II (*Contd.*)

Months	Plant components	I Plot		II Plot		III Plot	
		Biomass	Phosphorus	Biomass	Phosphorus	Biomass	Phosphorus
Oct.	Shoot	1655.0±46.5	3.25±0.14	1757.0±60.8	2.93±0.01	2272.0±74.3	3.17±0.09
	Rhizome	330.0±20.3	0.41±0.2	455.0±20.3	0.52±0.03	498.0±18.3	0.51±0.01
	Root	288.0±34.2	0.01±0.01	290.0±31.2	0.06±0.01	300.0±14.2	0.04±0.01
	Litter	70.0	0.0981	82.0	0.0820	100.0	0.0687
	Total	2350.0	3.83	2584.0	3.59	3170.0	3.78
Nov.	Shoot	1756.0±46.8	3.15±0.01	1826.0±43.0	2.79±0.05	2327.0±84.0	3.13±0.15
	Rhizome	342.0± 7.2	0.42±0.01	471.0±38.5	0.52±0.04	518.0±19.8	0.52±0.02
	Root	295.0± 6.6	0.08±0.01	295.0±15.2	0.06±0	305.0±39.0	0.04±0.01
	Litter	89.0	0.1078	105.0	0.1010	125.0	0.0796
	Total	2482.0	3.75	2697.0	3.47	3275.0	3.76
Dec.	Shoot	1810.0±35.4	3.61±0.20	1865.0±26.4	3.14±0.22	2357.5±65.2	3.54±0.14
	Rhizome	362.0±14.7	0.45±0.01	496.0±36.5	0.56±0.04	550.0±25.0	0.57±0.01
	Root	315.0±27.8	0.09±0.01	315.0±17.3	0.06±0.01	315.0±73.6	0.04±0.01
	Litter	115.0	0.1466	125.0	0.1312	145.0	0.0996
	Total	2602.2	4.29	2801.0	3.87	3367.0	4.24
	Annual net production						
	Shoot	2438.3	5.11	2132.5	4.21	1355.0	3.37
	Rhizome	124.0	0.18	186.5	0.19	196.75	0.22
	Root	240.0	0.19	220.0	0.10	145.0	0.09
	Litter	198.2	0.20	218.5	0.19	338.0	0.20
	Total annual net production						
		3000.5	5.68	2757.5	4.69	2034.7	3.88

I Plot—burnt on Jan. 30 and May 30, 1970
II Plot—burnt on Jan. 30, 1970 only
III Plot—unburnt (control)

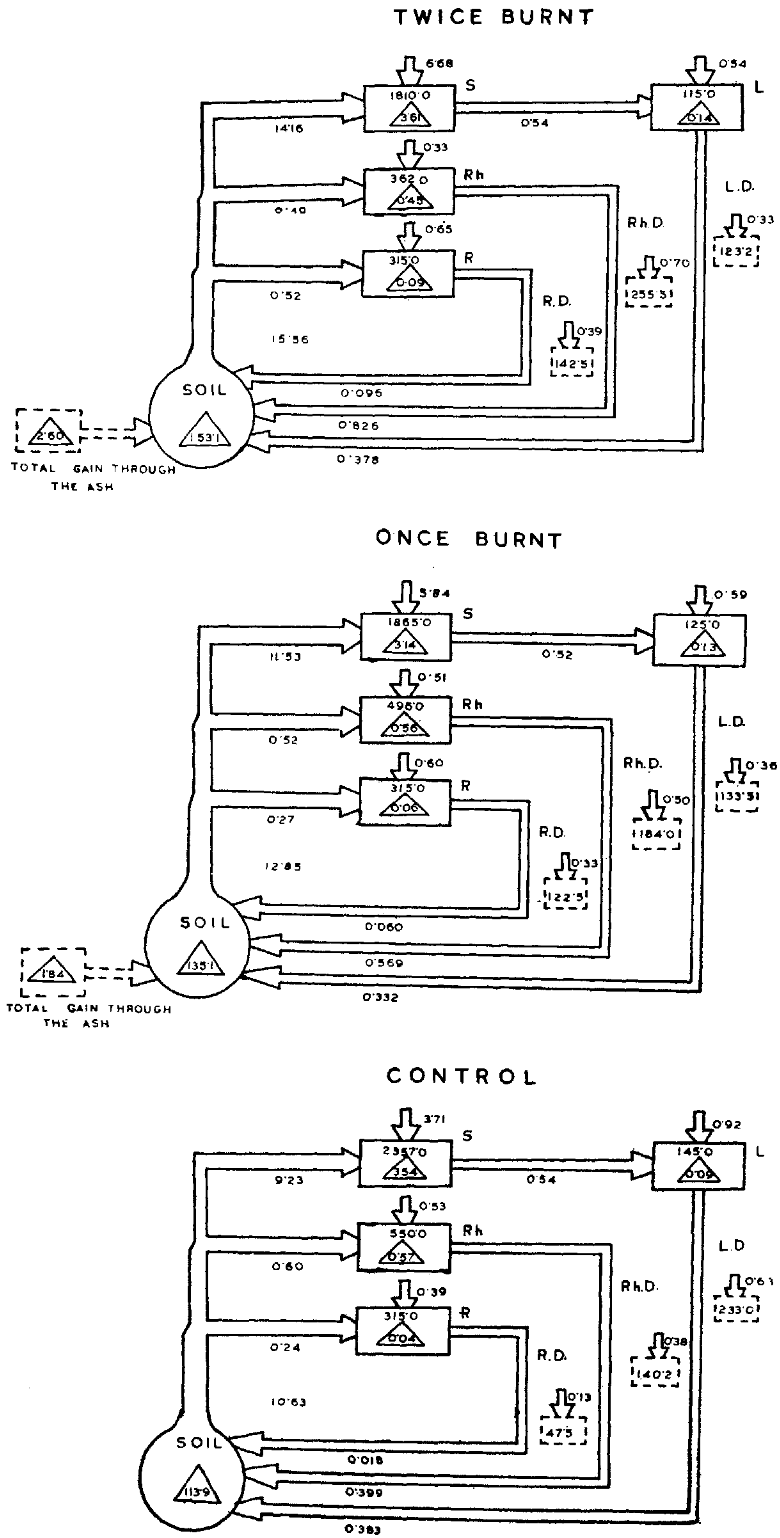
TWICE BURNT
6·68
1810·0
3·61
S
0·54
115·0
0·14
L
14·16
0·54
0·33
362·0
0·45
Rh
L.D.
0·40
Rh.D.
0·33
123·2
0·65
315·0
0·09
R
0·70
255·3
0·52
R.D.
0·39
15·56
142·5
SOIL
0·096
2·60
153·1
0·826
0·378
TOTAL GAIN THROUGH THE ASH
ONCE BURNT
5·84
1865·0
3·14
S
0·59
125·0
0·13
11·53
0·52
0·51
496·0
0·56
Rh
L.D.
0·52
Rh.D.
0·36
133·3
0·60
315·0
0·06
R
0·50
184·0
0·27
R.D.
0·33
12·85
122·5
SOIL
0·060
1·84
135·1
0·569
0·332
TOTAL GAIN THROUGH THE ASH
CONTROL
3·71
2357·0
3·54
S
0·92
145·0
0·09
L
9·23
0·54
0·53
550·0
0·57
Rh
L.D
0·60
Rh.D.
0·39
315·0
0·04
R
233·0
0·38
0·24
R.D.
140·2
10·63
0·13
47·5
SOIL
0·018
113·9
0·399
0·383

FIG. 1.

December. During the latter part of the year (viz., October to December) positive value for phosphorus content is obtained in the I plot whereas the II plot never reaches the positive value. Similarly, the biomass of underground plant components in the burnt plots also shows pronounced reduction throughout the year. The phosphorus content of underground parts in the I plot is regularly less but in the II plot except May rest months of the year show positive value. It is therefore concluded that the young re-growth after burning has a higher phosphorus concentration dry biomass.

TABLE III

Increase and decrease in the biomass and phosphorus content of burnt plots expressed as percentage of same parameters of the control plot

Months	Above ground				Underground			
	Shoot-biomass % of control		Phosphorus % of control		Rhizome+Root % Biomass of control		Phosphorus % of control	
	I Plot	II Plot	I Plot	II Plot	I Plot	II Plot	I Plot	II Plot
March	—60.2	—60.3	—52.7	—52.7	—16.7	—17.5	—2.0	0
May	—63.3	—63.2	—55.4	—55.4	—16.6	—16.6	—1.8	—1.8
June	—92.6	—68.1	—89.3	—61.3	—30.8	—14.1	—18.5	0
July	—53.9	—40.2	—41.5	—32.8	—28.0	—14.2	—15.1	0
Aug.	—31.7	—25.8	—7.4	—14.6	—22.4	—6.5	—11.5	0
Sept.	—28.6	—23.5	—2.95	—13.4	—23.1	—7.1	—13.3	+1.6
Oct.	—27.1	—22.6	+2.5	—7.5	—22.5	—6.6	—10.9	+5.4
Nov.	—24.5	—21.5	+0.63	—10.8	—22.6	—6.9	—10.7	+3.5
Dec.	—23.2	—20.9	+1.9	—11.2	—21.7	—6.2	—11.4	+1.6

I Plot—burnt on Jan 30 and May 30, 1970;
II Plot—burnt on Jan 30 only
III Plot—unburnt (control)

Uptake, transfer and release of phosphorus

The total annual uptake of phosphorus is 5.68 g/m^2 in the I plot, 4.69 g/m^2 in the II plot and 3.88 g/m^2 in the III plot as shown in Table IV. The values for the I and the II plots are respectively 46.3% and 20.8 higher as compared to that of the control plot. The uptake value of root is 0.19 g/m^2, 0.10 g/m^2 and 0.09 g/m^2 in the I, II and III plots

FIG. 1. Phosphorus cycle in *Dichanthium annulatum* stands under two frequencies of burning. *S*, Shoot; *Rh*, Rhizome; *R*, Root; *L*, Litter; *L.D.*, Litter decomposed g/m^2/day; *Rh.D.*, Rhizome decomposed g/m^2/day; *RD.*, Root decomposed g/m^2/day.

——→ denotes flow (P mg/m^2/day);
↓ denotes flow of biomass (g/m^2/day),
Soil depth 0–30 cm, soil pool shows the annual average value for Phosphorus.
▭ Contains peak biomass g/m^2 (upper figure) and its phosphorus content(figure given in △).
⁝- - -⁝ Shows total annual decomposed value g/m^2.

respectively. The I and the II plots respectively have 111.1% and 11.1% higher value over the figure of the control plot. The rhizome shows just reverse trend. The uptake values are 0.18 g/m², 0.19 g/m² and 0.22 g/m² for the I, II and III plots respectively. The uptake value is 18.1% less in the I plot and 13.6% less in the II plot as compared to the control plot. The total annual uptake of underground components (rhizome and root) is 0.37 g/m² (10.1% of total uptake) in the I plot, 0.29 g/m² (12.3% of total uptake) in the II plot and 0.31 g/m² (13.4% of total uptake) in the III plot. The uptake rate is 19.3% higher in the I plot and 6.4% lower in the II plot as compared to that of the control plot. The aboveground component (shoot) has uptake value 5.11 g/m² in the I plot, 4.21 g/m² in the II plot and 3.37 g/m² in the III plot. The values are 89.9% ,87.7% and 86.6% of their respective total annual uptake values. The I plot has 34.0% and the II plot has 19.9% higher uptake value as compared to that of the control plot. The transfer of phosphorus from the shoot component to litter compartment is 0.20 g/m² in the I plot, 0.19 g/m² in the II plot and 0.20 g/m² in the III plot. These values are 3.9%, 4.5% and 5.9% of their respective shoot values. The release of phosphorus from the litter compartment is 0.137 g/m² in the I plot, 0.121 g/m² in the II plot and 0.139 g/m² in the III plot. The respective phosphorus release from rhizome and root are 0.30 g/m² and 0.035 g/m² in the I plot, 0.20 g/m² and 0.022 g/m² in the II plot and 0.14 g/m² and 0.006 g/m² in the III plot. The total phosphorus release from different plant components (litter, rhizome and root) is 0.474 g/m², 0.351 g/m² and 0.292 g/m² in the I, II and III plots respectively. The release of phosphorus is 63.3% and 20.2 % higher in the I amd II plots respectively as compared to that of the control plot.

TABLE IV

Amount, uptake, transfer and release of phosphorus (g/m²/yr) Dichanthium annuletum in stand

	I Plot (Burnt on Jan. 30 and May 30, 1970)	II Plot (Burnt on Jan. 30, 1970 only)	III Plot (Unburnt control)
P-Amount in shoot	5.11	4.21	3.37
P-Transfer from shoot to litter	0.20	0.19	0.20
P-Amount in rhizome	0.18	0.19	0.22
P-Amount in root	0.19	0.10	0.09
P-Amount in underground components (rhizome + root)	0.37	0.29	0.31
Total P-uptake	5.68	4.69	3.88
P-Release from litter	0.137	0.121	0.139
P-Release from rhizome	0.30	0.20	0.14
P-Release from root	0.035	0.022	0.006
Total P-Release	0.474	0.351	0.292

DISCUSSION

The first burning on 30th January increases the amount of phosphorus in surface soil of the burnt plots during February as compared to the control plot. The lower depths, remain unaffected. This increase appears due to (i) the addition of phosphorus incorporated in the aboveground vegetation as soon as they are released at burning and (ii) the increase of soil *p*H. According to Austin and Baisinger (1955) in the forest soils of northwestern states of USA, the soil phosphorus was twice as high after burning. Tyron (1948) reported increase of phosphorus with addition of charcoal to clay, loam and sand. During March the amount of phosphorus increases at each depth of all the three plots. This is because of rainfall creating higher moisture content of the soil on 19th and 20th February and higher decomposition due to the increased microbial population (Pandey 1971). The higher amount in the burnt plots as compared to that of the control plot is due to the higher number of microbes and probably lower absorption due to the lack of vegetation. The amount of soil phosphorus decreases during the summer at each depth of all the three plots. The high temperature may be the major factor for this decrease since upper surface having high temperature shows more decrease in comparison to the lower depths having lower temperature. The high temperature of summer evaporates most of the soil moisture, thus reducing the microbial activity and in term the phosphorus release. Increase in soil phosphorus in the first plot during June is due to further addition of phosphorus through ash and change in *p*H of soil after second burning. The increasing amount of phosphorus is found during the rainy season at each depth of all the three plots. The maximum amount of soil phosphorus is obtained in the first plot whereas minimum in the third plot. In other words the increase in phosphorus content is correlated with fire frequency. The high amount in the burnt plots may also be due to higher decomposition as microbial population is also correlated with fire frequency. In winter a gradual decrease is obtained due to low decomposition since low temperature does not favour the microbial activity. Probably higher withdrawal by plants also causes the decrease in phosphorus concentration of soil.

First burning in January decreases the amount of phosphorus in shoot during March whereas it increases in the control plot. The decrease in the burnt plots is due to lower standing crop of shoot and increase in the control plot is caused by increased amount of phosphorus and moisture content in soil. Amount of phosphorus in rhizome decreases in each plot that may be due to upward translocation for the growth of shoot. During the summer the amount of phosphorus decreases in shoot of all the three plots. The reason may be the high temperature and low moisture content. The amount of phosphorus increases in rhizome of the second and the third plots due to downward translocation of food while the shoots are dying and the amount of phosphorus in rhizome of the first plot is decreased by upward translocation for the new growth of shoot. The amount of phosphorus decreases in root of each plot that also may be the result of high the temperature and low moisture. Rainy season favours the growth of plant due to sufficient soil moisture and high temperature, and the maximum amount of phosphorus in shoot, rhizome and root for each plot is recorded. The rate of increase of phosphorus content is most in the twice burnt plot and then in the once burnt plot and least in the control plot; the obvious reason is the higher amount of phosphorus in soil and high *p*H which enhances the uptake of phosphorus. A short decline in the amount of phosphorus of shoot, rhizome and root is found in the month of October. It can be explained due to depletion of soil moisture content. Occasional rainfall in the winter increases the amount of phosphorus in *D. annulatum* during November and December.

Although the total amount of soil phosphorus is high in the burnt plots yet it remains low in *D. annulatum* as compared to that of the control plot. The reason for it may be (i) the unavailability of phosphorus since it does not remain in available form for a longer time, it soon changes into unavailable form and (ii) the decreased biomass of *D. annulatum* in the burnt plots.

The amount of phosphorus in litter decreases during March and the rainy season due to high decomposition in these periods. During the winter and the summer phosphorus in litter is higher, since these periods are unfavourable for decomposition. The higher amount of phosphorus in litter of the burnt plots is due to its higher concentration in standing crop.

The decreased amount of phosphorus in total standing crop during first and second burning increases in the rainy season but its amount in the burnt plots does not exceed the amount of phosphorus found in the control plot. The characteristic of comparative unavailability of phosphorus may be the proper reason for decrease, although the soil may contain higher amount of phosphorus.

The biomass and plant phosphorus both decrease in the burnt plots as compared to those of the control plot but the percentage decrease in biomass is more than that of phosphorus. During the later part of the year the standing crops of the burnt plots show marked differences but their phosphorus contents remain slightly less as compared with that of the control plot. When once burnt and twice burnt plots are compared for biomass and phosphorus higher amount of phosphorus is found in the latter one. The explanation for this appears that post-fire sproutings are rich in phosphorus content whereas in the control plot the old and senile tissues have low phosphorus content. Again it is true for the twice burnt plot in comparison to the once burnt plot for the same reason. So increase in the phosphorus content in the regrowth is understandably high in relation to biomass with fire frequency.

The total annual uptake of phosphorus in all the three plots indicates that only a small fraction (3.71% in the first plot, 3.47% in the second plot and 3.40% in the third plot) of the total phosphorus in the system is involved in the biological circulation. The transfer values of phosphorus from shoot to litter is almost similar in all the three plots although the litter biomass decreases with the frequency of fire. It is due to the higher concentration of the phosphorus in per gram dry weight of litter. Phosphorus release is also higher in the burnt plots since (i) the decomposition rate of rhizome, root and litter is higher in these plots and (ii) the amount of phosphorus present in per gram dry biomass is higher in the burnt plots.

ACKNOWLEDGEMENT

The author is deeply indebted to Prof R. Misra, FNA, FWA, Ex. Head of the Department of Botany, Banaras Hindu University, for his valuable guidance and inspiration.

REFERENCES

Austin, R. C., and Baisinger, D. H. (1955). Some effects of burning on forest soils of Western Oregon and Washington. *J. For.*, **53**: 275-280.

Jackson, M. L. (1958). Soil Chemical Analysis. Prentice Hall, N. J.

Pandey, A. N. (1971). *Effect of Burning on Dichanthium annulatum Grassland.* Ph.D. Thesis, Banaras Hindu University (India).

———— (1974). Short-term effect of seasonal burning on the composition of *Dichanthium annulatum* stands at Varanasi. *Proc Indian natn. Sci. Acad.*, **40**, Part 3, 107-112.

———— (1974). Short-term effect of burning on the above ground production of *Dichanthium annulatum* grassland stands at Varanasi. *Bull. Sci. trop. Ecology*, **15**, 152-153.

Pandey, A. N. (1976). Short-term effect of burning on the standing crop and cycling of nitrogen in soil vegetation components of *Dichanthium annulatum* stands at Varanasi. *Bull. int. Soc. trop. Ecology*, (*in press*)

Tyron, E. H. (1948). Effect of charcoal on certain physical, chemical and biological properties of forest soils. *Ecol. Monogr.*, **18**, 81-115.