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Effect of seasonal burning on biomass, net primary productivity and recovery in *Iseilema* grassland community of Bundelkhand region (U.P.), India

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Abstract
Present study was undertaken to assess the recovery in terms of biomass following seasonal burning of protected *Iseilema laxum* grassland at Orai (Jalaun), India over a period of one year. The experimental site was divided into three equal plots. Plot I was burnt twice (January and May), plot II was burnt once (January) and plot III was kept unburnt and was used for comparison. Burning stimulated the growth of shoot and root components of the plant but disfavoured the growth of rhizomes. However, average total plant biomass of burnt plots (1284 gm^{-2} and 1446 gm^{-2} in plot I and II respectively) could not return to the level of control plot (2196 gm^{-2} in plot III). Productivity of rhizome declined with the frequency of burning whereas it increased for shoot and root. The concomitant decline in the productivity of rhizome, the most critical component of perennial grassland commands caution. Long-term studies are necessary to establish the critical limit to which rhizome productivity and biomass can decrease yet the grassland can still be maintained for sustained increased level of production. Summer burning prior to rains showed promising result for higher production and thereby the greater recovery rate of biomass as compared to winter burning.

Key words: Burning, Grassland, Production, Protected, Recovery, Sprouting, Stimulus.

Introduction
Annual burning constitutes an important aspect of the ecology of tropical grasslands. Fire can be a significant component of the biotic environment. The importance of burning in determining the distribution and form of many species as well as the composition, production and recovery has been recognised. A considerable amount of work on vegetation burning has been done (Ahlgren, 1960; Wright and Klemmedson, 1965; Old, 1969; Pandey, 1974a, b and Wright *et al*. 1976).

Plant communities when subjected to fire take considerably long time for restoration of their original composition and structure. According to Thorhaug (1980), recovery of disturbed ecosystems is influenced by the geographical and climatic factors and the ecological conditions of the site. Pandey and Singh (1985) suggested that system-level properties such as biomass, nutrient regeneration, *etc.,* are better indicators of recovery than transient species composition. The present study deals with the pattern of recovery of biomass in a tropical grassland over a period of one year following controlled seasonal burning.

Materials and Methods
Study site: The study site, Bohadpura Sheep Farm, Orai (Jalaun) is located in a protected area which lies between 25^0 29' N latitude and 79^0 37' E longitude at an elevation of 141.6m above mean sea level. The climate of the site is dry sub-humid. Mean monthly maximum temperature ranged between 13.9 to 34.2^0C and mean monthly minimum between 7.6 to 27.7^0C. Lowest temperature occurred in January and highest in May. The mean annual rainfall was 1070 mm with maximum rainfall in August and minimum in November. Out of total annual rainfall, 86% occurred in the rainy season. The year is divisible into three distinct seasons, *viz.,* cool and dry winter (November to February), hot and dry summer (March to June) and warm and wet rainy (July to October).

The experimental site was homogeneously dominated by a perennial grass species, *Iseilema laxum* (Hack.). For the experimental purpose, three equal plots (each 24x12 m) were demarcated within the study site. Plots I and II were selected for controlled burning and plot III was kept unburnt (control) for comparison. Four subplots, each of 5x5 m size, were marked randomly in each of the three plots. In plots I and II, the vegetation was removed from a 1m wide strip around each subplots (except for contiguous subplots, where fire-break was about 0.4 m wide). The vegetation beyond this denuded strip acted as break for surface winds. The vegetation of the subplots in Plots I and II was burnt on 30 January, 2009. Fire was set at one or two places at the margin and was allowed to spread over the ground surface burning all the standing crop since the vegetation was nearly dry. Plot I was again burnt on 30 May, 2009 in the same way.

Sampling: Standing crop and net production were estimated by "short-term harvest method' (Odum, 1960). Biomass sampling was done at monthly interval (except March and May months representing bimonthly samples) over a period of one year. On each sampling date, five soil blocks (monoliths), each of 25x25x30 cm size were excavated at random (within the four subplots marked) from each plot. The excavated blocks were washed under a fine jet of water to remove soil particles adhering to the underground parts of the plant. The plant samples were fractioned into shoot, rhizome and root components, oven dried and weighed. The litter samples were collected from the excavated blocks from each plot before washing the monoliths.

Net production was estimated as the increase in biomass between two consecutive samplings. Aboveground production was calculated by summing the concomitant production values for shoot and litter through out the year (Singh *et al.*, 1975). The sum of production values for rhizome and root represented the estimate of total underground production. Dry matter disappearance was calculated using the following expressions (Singh *et al.*, 1979).

L. D. = Initial biomass of litter + Litter production - Final biomass of litter

Rh. D. = Initial biomass of rhizome + Rhizome production - Final biomass of rhizome

R. D. = Initial biomass of root + Root production - Final biomass of root

The sum of values obtained for L.D, Rh.D. and R.D. yielded total disappearance (T.D.)

Relative growth quotient (RGQ) was calculated as:

$$RGQ = \frac{Bn_2 - Bn_1}{Bn_1} \;/\; tn_2 - tn_1$$

where, Bn_1 and Bn_2 are biomass in g m^{-2} respectively on sampling dates n_1 and n_2 and tn_2 and tn_1 is the time interval in days between sampling dates n_1 and n_2.

Results and Discussion

Aboveground standing crop

Shoot: Within one year period, there were two peaks (March and December) in plots I and II, whereas in plot III only one peak (December) was discernible (Fig. 1). In plots I and II beginning from a zero post-burning value the new shoot, sprouts grew markedly culminating into a peak in march (608 ± 7g m^{-2} and 612 ± 9 g m^{-2} respectively). In this period no marked growth was recorded in plot III. During summer, shoot biomass declined from March through June in all the three plots. Since plot I was reburnt on May 30, standing crop in June was remarkably low in this plot. Subsequently as the vegetation grew rapidly through the rainy season and with a lower pace later on *i.e.* during winter, it attained the peak biomass in December in all the three plots. However, standing crop of shoot in plots I and II could not recover to the level of plot III.

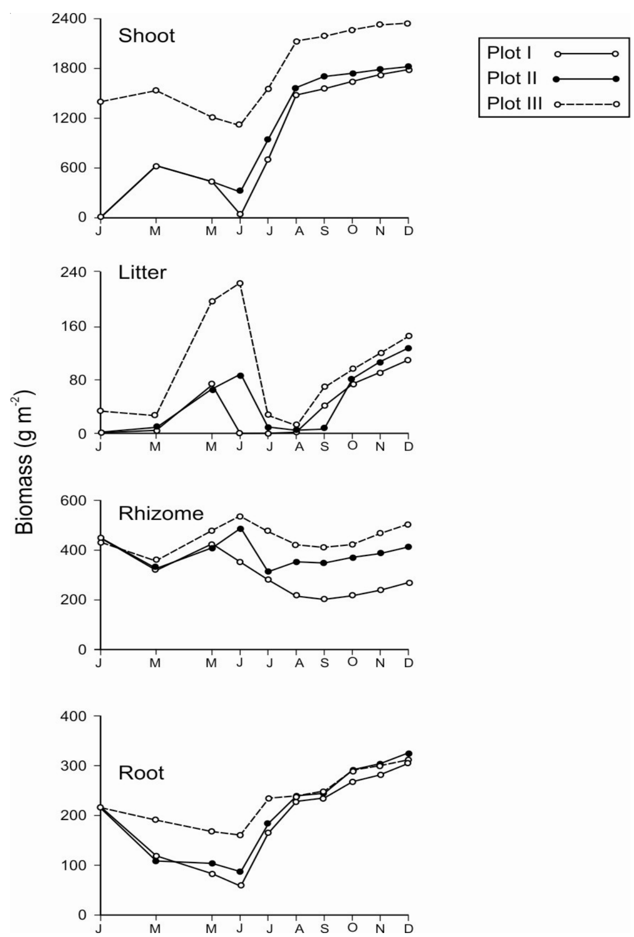

Fig 1. Biomass in different components of plant in three experimental plots during different months of the year 2009. Arrows indicate the months of burning S.E. corresponded with biomass values and is not shown to maintain clarity of the diagram.

The first burning on 30 January decimated all the standing crop of shoot in the burnt plots. New shoot sprouted from the rhizomes shortly after burning because of the removal of apical dominance due to the killing of shoots by fire and reserve mobilization. The shoot sprouts grew fast and attained the first peak in March. This growth was supported by small rainfall events on February 19 and 20 and higher nutrient concentration (nitrogen and phosphorus) in the soil exchanging pool after burning (Pandey, 1976a, b). Nitrogen status was further improved by increasing leguminous population subsequent to burning (Pandey, 1974a, b, c). Rainy season provides suitable conditions for growth with suitable ambient temperature and sufficient moisture in the soil. Consequently, plants grew vigorously attaining maximum dry matter production in August in all the three plots. The burnt plots showed higher production because of improved nutrient status of soil, less mutual shading and younger tiller population. The magnitude of production and relative growth quotient (P/ B) indicated that the young shoots of the burnt plots were more active than the mature shoots of plot III. Old (1969) reported that the post-fire increases in soil nutrient levels, soil temperature levels, surface light levels, removal of surface litter and removal of senescent plant parts had been stimuli to both vegetative and seedling growth in Illinois prairie. In present study, the higher productivity and relative growth quotient on plot I in December indicate that the activity of shoot biomass in the twice burnt plot lasts longer than that in the once burnt plot. However, the burnt plots maintained lower standing crop of shoot throughout the year as compared to the control plot although the annual dry matter production was significantly higher ($P < 0.01$). Similar results were reported by Hadley and Kieckhefer (1963) for the productivity of the stands of *Andropogon gerardi* and *Sorghum nutants* in central Illinois. Mall and Mehta (1978) recorded a significant increase in the live green aboveground biomass following burning in a tropical grassland in India. Again in the present study though the biomass was less but annual net production was significantly higher ($P < 0.01$) in the twice burnt plot as compared to that in the once burnt plot. It can, therefore, be inferred that burning of *I. laxum* grassland in summer season prior to rains is a promising stimulator of herbage production.

Litter: The litter biomass was reduced to zero in plot I and II after the first burning but it increased through summer and peaked respectively in May and June (Fig. 1). Since the second burning again consumed the pre-existing litter in plot I, the first peak appeared in May only. In plot III also, litter biomass attained a peak value in June. Following the first peak, litter biomass decreased through the rainy season and attained the lowest values in August in plots II and III. The amount of litter consistently remained zero in plot I until August. Thereafter, the litter biomass increased again and reached a second peak in December in all the three plots.

Litter production was maximum during the summer season because of the senescence of plant parts. However, in the burnt plots, litter production was lower than that in the control plot because of their younger new regrowth. During rainy season undetectable litter production from the lush shoot and faster decomposition of dead plant material reduced the amount of litter in all the three plots. Understandably, total annual litter production was maximum in the control plot and least in the twice burnt plot. Similar results were obtained by Tester and Marshal (1961) on a native prairie in northwestern Minnesota.The total aboveground standing crop (shoot + litter) followed a temporal pattern almost similar to that of shoot in all the three plots (Table 1).

Underground standing crop

Rhizome: Two peaks were recorded for each component within the year (Fig. 1). Following the first minimum in March, rhizome biomass increased reaching a first peak in May (plot I) or in June (plots II and III). The time difference can be attributed to the shoot sprouting and growth processes after second burning of plot I. Standing crop of rhizome declined through rainy season and reached a second minimum in September. Subsequently, the standing crop of rhizome increased reaching a second peak in December. However, the magnitude of rhizome biomass was maximum in plot III and least in plot I throughout the year.

The net dry matter accumulation in rhizome declined during the active growth periods, *i.e.*, March and rainy season, whereas the converse was true for dry summer and winter seasons. The intra plant transfers, *i.e.*, rhizome to growing parts and back to rhizome might be responsible for this pattern. Consequently the standing crop of rhizome followed a fluctuation pattern almost reverse of shoot. Moreover, annual dry matter production in rhizome decreased (Table 2) with frequency of fire indicating the utilization of reserves in rhizome to support regrowth following burning and insufficient replenishment later on. On the other hand, the annual net production of roots increased (Table 2) with the frequency of fire partially at the expense of rhizomes.

Table 1. Monthly variation in plant biomass (g m^{-2}) in three experimental plots of *Iseilema* grassland community

Months/A.B.	Plots	Aboveground	Underground	Total	
		(Shoot + Litter)	(Rhizome + Root)	Plant	U.G.
	I	00	00	00	00
January	II	00	00	00	00
	III	1464	686	2150	2.1
	I	608	510	1118	1.2
March	II	612	505	1117	1.2
	III	1585	618	2203	2.5
	I	512	560	1072	0.9
May	II	509	560	1069	0.9
	III	1425	677	2102	2.1
	I	58	483	541	0.1
June	II	428	606	1034	0.7
	III	1335	709	2044	1.9
	I	715	535	1250	1.3
July	II	940	642	1582	1.4
	III	1603	753	2356	2.1
	I	1457	547	2004	2.6
August	II	1582	655	2237	2.4
	III	2148	713	2861	3.0
	I	1613	542	2155	2.9
September	II	1733	660	2393	2.6
	III	2278	713	2991	3.2
	I	1702	593	2292	2.8
October	II	1809	720	2529	2.5
	III	2342	773	3115	3.0
	I	1817	612	2429	2.9
November	II	1901	741	2642	2.5
	III	2422	798	3220	3.0
	I	1895	652	2547	2.9
December	II	1960	786	2746	2.5
	III	2473	840	3313	2.9
Average	I	866	419	1284	
(12 months)	II	956	490	1446	
	III	1590	607	2196	

Plot I - Burning 30 January & 30 May
Plot II - Burning 30 January
Plot III - Unburnt

Table 2. Monthly variation in net primary production (g m^{-2}) in three experimental plots of *Iseilema* grassland community

Months	Plots	Shoot	Litter	Aboveground	Rhizome	Root	Underground	Total
	I	-	-	-	-	-	-	-
January	II	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-
	I	603	05	608	-	-	-	608
March	II	603	09	612	-	-	-	612
	III	128	-	128	-	-	-	128
	I	-	72	-	80	-	80	80
May	II	-	66	-	65	-	65	65
	III	-	175	-	86	-	86	86
	I	58	-	58	-	-	-	58
June	II	-	20	-	58	-	58	58
	III	-	32	-	37	-	37	37
	I	657	-	657	-	100	100	757
July	II	600	-	600	-	92	92	692
	III	472	-	472	-	82	82	554
	I	742	02	744	-	65	65	809
August	II	644	-	644	-	58	58	702
	III	566	-	566	-	06	06	572
	I	113	41	154	-	10	10	164
September	II	103	48	151	-	07	07	158
	III	85	65	150	-	02	02	152
	I	54	35	89	11	30	41	130
October	II	44	32	76	15	45	60	136
	III	16	28	44	12	48	60	104
	I	96	17	113	09	10	19	132
November	II	64	28	92	11	10	21	113
	III	58	22	80	23	02	25	105
	I	60	20	80	26	22	48	128
December	II	39	20	59	17	18	35	94
	III	23	28	51	27	15	42	93
				Annual net production				
	I	2383	192	2503	126	237	363	2866
	II	2097	223	2234	166	230	406	2640
	III	1348	350	1491	185	155	340	1831

Root: One peak was recorded for each plot (fig. 1). Root biomass declined through summer attaining the lowest value in June. Thereafter, root biomass increased regularly and peaked in December. Root biomass in plots I and II was lower than that in plot III until November and became almost equal to it in December.

There were two peaks in plots I and III whereas for plot II one peak was recorded for total underground standing crop (rhizome + root) (Table 1). The first minimum value appeared in March in all the three plots. The underground standing crop in plot I consistently increased after first minimum in March and attained a peak value in December. However, total underground biomass was maximum in plot III and least in plot I throughout the year.

Total standing crop of vegetation: The overall plant biomass reflected a seasonal variation with the maximum value in December and minimum value in June (Table 1). Plot III maintained the highest standing crop throughout the year. The aboveground / underground ratios were lower throughout the year in plots I and II compared to plot III (Table 1). The values declined through summer until June and increased from July onwards in each plot.

Net primary production

Aboveground: In plots I and II, the first growth peak in March resulted from net accumulation at the rate of 9.96 g m^{-2} day^{-1} (Table 2). Net accumulation of dry matter was not evident during the summer season except for plot I in June. The maximum net accumulation occurred in August. During this month, daily dry matter input averaged at 24.21 and 18 g m^{-2} (or 33,22 and 11 mg g^{-1} RGQ), respectively in plots I, II and III. Winter months were characterized by low production. Daily net production in December averaged at 2.6, 1.9 and 1.6 g m^{-2} (or 1.0, 1.4 and 07 mg g^{-1} RGQ), respectively in plots I, II and III. The overall annual net production averaged at 6.8 g m^{-2} day^{-1} in plot I, 6.1 g m^{-2} day^{-1} in plot II and 4.1 g m^{-2} day^{-1} in plot III.

Litter production was maximum in May and was not detectable in July - August (Table 2). Thereafter, litter production was again recorded. The trend and magnitude of total aboveground production were almost similar to those of shoot (Table 2).

Underground components: The net accumulation in rhizome was maximum in May in all the three plots (Table 2). There was no net production in June in plot I whereas a considerable production occurred in plots II and III. Net accumulation was not recorded during rainy season but the same occurred from October onwards in all the plots. Annual net production averaged at 0.34 g m^{-2} day^{-1} in plot I, 0.45 g m^{-2} day^{-1} in plot II and 0.51 g m^{-2} day^{-1} in plot III.

Net accumulation of dry matter in root did not begin until June in all the three plots (Table 2). The maximum net production occurred in July. Dry matter production once again increased considerably in October in each plot and persisted with a low rate until December. Total underground net production followed the trend and magnitude of those of rhizome during summer season and those of roots during the rainy season in all the plots (Table 2).

Total net primary production: Though the total net dry matter production was influenced by the seasonality in the year, burning provided stimulus for higher production in plots I and II over plot III (Table 2). The annual net production was higher in the burnt plots as compared to that of the control plot mainly due to the higher root production. Annual total net dry matter production was 1.4 times higher in the once burnt plot and 1.6 times in twice burnt plot as compared to the control plot (Table 2). In studying western sagebrush, Blaisdell (1953) found that the total yield of grass increased for three years following fire.

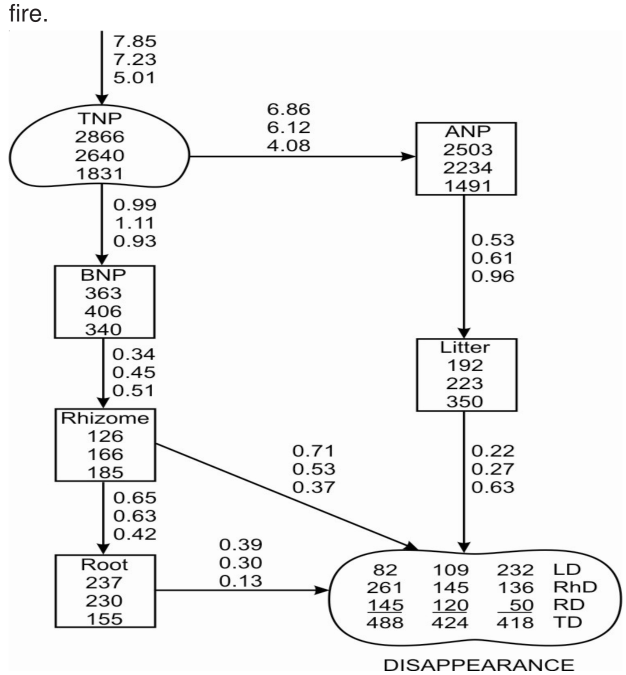

Fig 2. Dry matter flow in different components of *Iseilema laxum*. Compartments contain annual production values (g m^{-2}). Values on arrows show dry matter flow (g m^{-2} day^{-1}). The values in the compartments and on arrows are sequentially for the twice burnt, once burnt and control plots. TNP- Total net production, ANP- Aboveground net production, BNP- Belowground net production, L.D.- Litter disappearance, Rh.D.- Rhizome disappearance, R.D.- Root disappearance, T.D. Total disappearance.

Table 3. System transfer function

Components	System transfer function		
	Plot I	Plot II	Plot III
Total net production to aboveground net production	0.87	0.84	0.81
Aboveground net production to litter	0.07	0.09	0.23
Total net production to underground net production	0.12	0.15	0.18
Underground net production to rhizome	0.34	0.41	0.54
Underground net production to root	0.65	0.56	0.45
Litter to litter disappearance	0.43	0.44	0.66
Rhizome to rhizome disappearance	2.07	0.17	0.73
Root to root disappearance	0.61	0.48	0.32

It is evident from Table 3 that the per cent allocation of net production to shoot compartment was maximum in the twice burnt plot and least in the control plot. However, the conversion of shoot biomass into litter was more in the control plot. Dry matter transfer from total belowground net production to root was higher than that to rhizome in burnt plots whereas the pattern was reverse in the control plot. The rate of litter disappearance was remarkably lower whereas underground disappearance was considerably higher in the burnt plots as compared to those of the control plot. Dry matter flow, net production and disappearance in different components has been depicted in fig.2.

The recovery in terms of the standing crop after Ist year of burning varied for different components of the plant. Regardless of burning frequency, there appeared a complete recovery for roots and a little more than 77% for shoots. The rhizomes recovered 90% in the once burnt plot and only 66% in the twice burnt plot. The burning resulted into significant increase in shoot and root productivity, thus indicating considerable favourable effect. However, the concomitant decline in the productivity of rhizomes, the most critical component of perennial grassland, commands caution. It would be necessary to plan and carry out further long term studies to establish the critical limit to which rhizome productivity and biomass can decrease yet the grassland can still be maintained for sustained increased level of production.

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