Korean J. Ecol. Sci., 1(2): 93~100, 2002

Impact of Surface Fire on the Dynamics of N_2 - Fixing and P - Solubilizing Microbial Population in Natural Grassland Soils, Southern India

Manian, S[1]., S. Paulsamy[2], K. Senthilkumar[1] and Bong-Seop Kil[3]*

[1]Department of Botany, Bharathiar University, Coimbatore - 641 046 Tamil Nadu, India.
[2] Department of Botany, Kongunadu Arts and Science College, Coimbatore - 641 029 Tamil Nadu, India.
[3]Division of Life Science, Wonkwang University, Iksan 570-749, Korea.

ABSTRACT: Dynamics of certain N_2 fixing bacteria such as *Rhizobium, Azospirillum* and *Azotobactor*, nodule number in dominant legume, *Atylosia trinervia*, P-solubilizing bacteria, actinomycetes and fungi were studied in unburned and burned site of natural grassland, southern India. Population of N_2 - fixing bacteria, P-solubilizing bacteria, fungi and nodule number in legume increased significantly in burned sites. On the other hand, the actinomycetes population remained unchanged. Thirty six species of fungi with tricalcium phosphate solubilizing ability were recorded. The most efficient P-solubilizing fungi recognised in the soils of the study sites are *Absidia ramosa, Gongronella butlerii, Mortieralla spinosa, Mucor racemosus, Rhizopus nigricans, R. stolonifer, R. oryzae, Aspergillus fumigatus, A. nidulans, A. niger, Theilavia terricola* and *Cheatomium lunasporium.*

Key words: Grasslands, Nodule number, N_2-fixing and P-solubilizing microbes, Surface fire

INTRODUCTION

World' s grasslands have been classified in many ways, chiefly on the basis of climatic factors (Moore and Biddescombe 1964). Apart from climatic factors, edaphic, physiographic and biotic factors including fire play a major role in deciding the distribution of grasslands (Thomas 1960). Grasslands are well adapted to fire with greatest adaptation being the species growing in more and humid areas where, the fire frequency has been the highest. Soil microorganisms are important agents in nutrient cycling in all ecosystems and they are extremely sensitive to environmental changes. Since the action of both heat and ash modify the chemical and physical status of soil following fire (Senthilkumar *et al.* 1995, Senthilkumar and Manian 1998), alterations in microbial populations may be expected.

In the present study, N_2-fixing bacteria and nodule number in the roots of dominant legume, *Atylosia trinervia*, the changes in population of P-solubilizing bacteria, fungi and actinomycetes in the soils of burned and unburned sites, after two consecutive annual surface fires were studied to know the potential of prescribed fire in the soil fertility.

STUDY SITE

The study was carried out in a high level natural grasslands of Kundah plateau, Western Ghats, Tamil Nadu, southern India which extends over an area of ca. 1000 hectares. The latitude and the longitude were 11^0 13′ N and 76^0 39′ E respectively with an elevation range of 2,150 to 2,450 meters above m.s.l. The shola forest adjacent to the study sites provides shelter to the wild animals. The temperature ranges from 4-29°C and the intensity of solar radiation is generally very high. The climatic factors of the study area for the study period is given in Table 1.

During second week of April 1992, a surface fire cleared the grasslands of study area completely except a patch of ca.60ha, since it is protected by a natural fire barrier, stream. An alleged tribal fire in the first week of April 1993, burned a few hundred hectares in the area where the burning occurred year before. Observations were made at monthly intervals for 2 years from April 1992 on both the naturally isolated unburned patch and the burned area of grassland. Since both sites are adjacent to each other they were comparable in topography, soil type and vegetation.

METHODS

Sampling

Ten random soil samples of 100g each were collected from the rhizosphere of A_1 (0-10 cm) layer of unburned and burned sites in fresh polypropylene bags using sterile spatula.

* Author for correspondence; Phone: 82-63-850-6577, Fax: 82-63-857-8837, e-mail: bskil@wonms.wonkwang.ac.kr

Table 1. Climatic factors of the study area

Year and month		Temperature(℃)		Rainfall		Relative humidity(%)	
		Max.	Min.	Quantity(mm)	Rainy days	3:00PM	7:00AM
1992	Mar	23.2	12.1	0.0	0	80	48
	Apr	24.8	13.4	12.0	3	75	37
	May	25.6	16.5	78.0	9	95	42
	Jun	21.1	16.2	190.0	12	88	54
	Jul	21.3	16.5	146.0	11	91	67
	Aug	21.2	17.3	191.6	13	82	51
	Sep	23.0	16.7	184.6	12	95	62
	Oct	21.1	14.6	208.6	14	94	76
	Nov	20.2	15.8	95.1	4	90	67
	Dec	19.0	10.6	0.0	0	98	70
1993	Jan	20.6	11.3	0.0	0	95	66
	Feb	20.8	11.7	16.0	1	98	72
	Mar	23.5	12.9	0.0	0	95	46
	Apr	26.6	16.5	32.0	4	98	56
	May	28.1	17.6	113.0	8	95	42
	Jun	23.8	17.8	138.0	9	84	58
	Jul	20.6	16.6	236.0	8	88	61
	Aug	20.9	16.5	295.5	6	90	58
	Sep	22.6	16.0	483.6	12	90	66
	Oct	22.2	17.1	824.1	15	92	70
	Nov	17.2	12.7	920.0	6	98	72
	Dec	16.1	9.7	0.0	0	85	58
1994	Jan	15.2	9.7	0.0	0	94	54
	Feb	17.2	11.8	28.0	2	88	62
	Mar	20.2	11.7	88.6	4	90	45
	Apr	22.2	15.2	136.6	4	80	60

Immediately after the collection, sample was stored in ambor colour bottle and brought to the laboratory for enumeration of microbial population. Dilution plate method of Jenson (1968) was employed for the enumeration of N_2- fixing bacteria (*Rhizobium, Azospirillum* and *Azotobacter*), P- solubilizing bacteria, actinomycetes and fungi. The media employed are Yeast extract mannitol agar medium for *Rhizobium*, Nitrogen-free bromothymol blue (NBF) medium for *Azospirillum*, Ashby' s agar medium for *Azotobactor*, Tricalcium phosphate medium for P-solubilizing bacteria and fungi and Pikowikaya' s agar medium for actinomycetes. The composition and the method of preparation are as per Sundararao and Sinha (1986).

Observation

The slimy colourless *Rhizobium* colonies appeared after 48 h of incubation is easily differentiated from other colonies of bacteria (the forms other than *Rhizobium* absorb Congored 3%). Minute dot like white colonies of *Azospirillum* developed below the surface of semi solid agar medium after 60 h of incubation and the *Azotobactor* appeared as slimy colourless colonies after 96 h of incubation which turned brownish black upon maturation. The P-solubilizing bacteria (PSB) and fungi (PSF) were observed respectively on the 2nd and 5th days of incubation. The P-solubilizing actinomycetes (PSA) appeared as small, white, chalky colonies on 48 h of incubation. All the P-solubilizing microbes produced clear zones on the agar medium around their colonies. Ten replicate plates were maintained for each of the organism studies. The P- solubilizing fungi were further brought to pure culture in the same medium and identified up to species level and their percentage occurrence, percentage frequency and frequency class were calculated using the following formulae:

$$\text{Percentage occurrence} = \frac{\text{Number of colonies of particular species}}{\text{Total number of colonies of all species}} \times 100$$

Percentage occurrence indicates the relative abundance of each fungal species at every sampling month;

$$\text{Percentage frequency} = \frac{\text{Number of sampling months in which the fungal species recorded}}{\text{Total number of sampling months}} \times 100$$

Percentage frequency indicates the persistence of a particular species over a period of time. Based on the percentage frequency of the fungi observed were categorised as dominant' (81-100%), 'common' (61-80%),' frequent' (41-60%),' occasional' (21-40%), or 'rare' (1-20%) (Senthilkumar *et al.* 1993a).

Enumeration of nodule

The nodule numbers in dominant legume, *Atylosia trinervia* were counted by constructing five random quadrats (50x50 cm each) in the study sites during every sampling time. The monoliths were soaked in water so as to remove the soil and the plant components were brought to the laboratory and sorted out into belowground and aboveground parts. The nodule numbers were counted from the roots of the legume and the values were expressed as the number per square meter. The *Rhizobium* nodules were confirmed by using the method of Subbarao (1986).

Statistics

The data on N_2- fixing and P- solubilizing microbial population on monthly basis were subjected to statistical analysis to determine their significance at 5% level. The Duncan' s New Multiple Range Test (DMRT) was used to find the differences among replicates. Correlation between certain edapho-climatic factors and microbial population also obtained. The data of moisture content, pH, N, P, K, organic matter and CO_2 evolution were obtained from Senthilkumar and Manian (1998).

RESULTS

The population of *Rhizobium*, *Azospirillum* and *Azotobactor* recorded in the A_1 layer and the nodule counts of the legume, *Atylosia trinervia* in burned and unburned sites are presented in Fig.1. The soil rhizobial populations ranged between 10.3 - 36.1 x 10^4 and 4.5 - 95.5 x 10^4 / g soil respectively for the unburned and burned sites. The population increased significantly in the burned site during both the years of observation (Table 2). However, the burning months were characterized by a marked decrease in the rhizobial population (Fig.1). The rhizobial nodular count as observed in the legume, *Atylosia trinervia* also was increased significantly in the burned site (Table 2) during the second year (1993-94) of observation. In addition , the visual observation revealed that the density of the legume was higher in the burned site. However, during first year (1992-93) nodule number in the burned site was on par with unburned site (Fig.2). In both the years of study, the nodule number was not counted during the burned month on April, due to the difficulties in the identification of species in the absence of their shoot system. Among the N_2-fixing microbes studied in the grasslands, the population of *Azospirillum* was predominant, with 24.8 - 118.8 x 10^5 and 4.4 - 276.5 x 10^5 /g

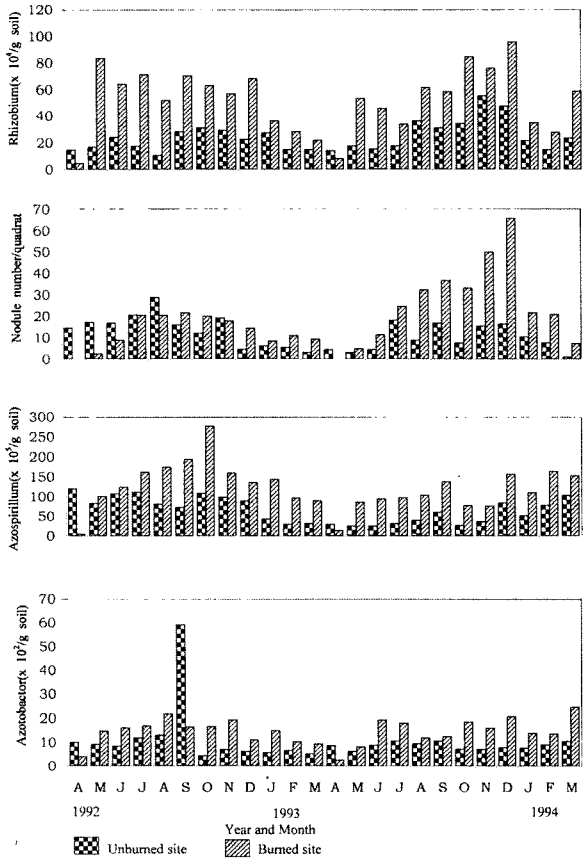

Fig. 1. Changes in the population of nitrogen fixing soil microbes and legume root nodule as influenced by burning in the study area.

Table 2. Population of N_2-fixing and P-solubilizing microbes in the A1 layer of soil of unburned and burned sites during the study period

Year	Site	Rhizobium (X 10^4/g soil)	Azospirillum (X 10^5/g soil)	Azotobactor (X 10^2/g soil)	Number of nodule (individuals / 50 × 50 cm quadrat	P-Solubilizing bacteria (X10^4/g soil)	P-Solubilizing actinimycetes (X10^2/g soil)	P-Solubilizing actinimycetes (X10^5/g soil)
1992-93	UB	21 a*	81 ab	7.7 a	14 a	15 a	6.1 b	14 a
1992-93	B	51 b	131 c	14 b	12 a	31 b	7.8 b	18 ab
1993-94	UB	27 a	49 a	8.5 a	9.9 a	16 a	4.7 a	15 a
1993-94	B	53 b	110 c	15 b	26 b	30 b	6.4 ab	22 b

UB and B respectively are unburned and burned sites.

* In columns means followed by same letter are not significantly different ($p<0.05$).

Table 3. The P-solubilizing fungi, their mean percentage occurrence (means of 12 sampling months), percentage frequency and frequency class in unburned and burned sites during two years(April 1992 to March 1994) of investigation

Name of fungus	Year 1992-93						Year 1993-94					
	Mean percentage occurrence		Percentage frequency		Frequency class		Mean percentage occurrence		Percentage frequency		Frequency class	
	UB	B	UB	B	UB	B	UB	B	UB	B	UB	B
Absidia ramosa	4.2±3.0	3.4±2.1	75	83	C	D	3.6±2.9	3.4±2.4	83	100	D	D
Gongronella butlerii	5.3±4.9	4.9±0.8	92	100	D	D	4.5±3.1	2.6±1.9	92	100	D	D
Mortierella spinosa	1.0±1.6	1.6±0.3	42	75	F	C	2.0±1.7	2.8±1.9	67	92	C	D
Mucor racemosus	3.0±1.7	1.7±0.9	67	83	C	D	3.1±2.9	1.5±1.0	83	92	D	D
Rhizopus nigricans	4.2±3.8	3.8±3.1	100	92	D	D	4.6±1.8	3.6±3.1	100	92	D	D
R. stolonifer	0.5±0.6	0.6±6.6	33	33	O	O	0.5±3.4	0.5±5.6	17	25	R	O
Pacilomyces variotii	0.9±1.9	2.0±1.3	50	75	F	C	2.6±1.7	1.8±1.3	75	92	C	D
Chaetomium lunasporium	0.6±1.1	1.1±6.3	33	50	O	F	0.6±3.7	1.6±1.7	25	100	O	D
Neurospora sp.	1.4±6.1	0.04±6.0	33	8.3	O	R	1.2±3.2	0.2±9.1	42	8.3	F	R
Thielavia terricola	2.6±2.6	3.8±2.6	75	92	C	D	1.1±5.1	2.2±1.1	58	100	F	D
Alternaria alternata	2.9±2.2	2.4±2.2	83	83	D	D	4.4±3.4	3.0±3.8	83	100	D	D
A. diathicola	0.7±2.2	1.2±2.2	25	42	O	F	0.6±0.2	0.3±1.3	25	17	O	R
Aspergillus awamori	1.1±4.8	1.3±1.3	50	75	F	C	1.9±1.2	1.8±1.5	67	83	C	D
A. flavipes	0.9±6.4	2.0±7.5	58	42	F	F	1.5±1.7	2.2±1.4	75	100	C	D
A. flavus	1.7±1.7	2.0±3.2	75	67	C	C	1.9±1.0	1.8±1.7	92	92	D	D
A. fumigatus	8.5±5.8	8.1±4.9	92	100	D	D	4.2±1.7	7.8±6.1	100	100	D	D
A. nidulans	8.8±6.1	5.8±6.7	100	83	D	D	7.8±1.1	7.1±5.0	92	100	D	D
A. niger	21±5.6	16±11	100	100	D	D	16±3.3	14±7.1	100	100	D	D
A. terreus	2.4±1.9	2.8±1.1	92	92	D	D	2.2±1.3	2.0±2.3	100	92	D	D
A. versicolor	2.2±2.2	1.5±7.5	75	67	C	C	3.1±2.1	1.6±1.8	92	100	D	D
Cladosporium cladosporioides	2.4±1.7	1.8±1.2	75	83	C	D	2.8±1.9	2.9±1.4	92	100	D	D
Fusarium oxysporum	1.2±1.1	0.7±7.2	42	50	F	F	2.2±1.7	1.8±1.3	83	83	D	D
F. solani	1.8±1.8	1.6±1.1	92	83	D	D	2.1±1.7	2.4±1.2	83	92	D	D
Penecilluum citrium	1.0±7.3	3.5±2.3	42	100	F	D	2.2±1.1	1.8±1.7	75	83	C	D
P. digitatum	2.0±0.9	2.2±7.8	75	58	C	F	2.8±1.2	1.4±1.1	75	92	C	D
P. implicatum	2.2±1.7	1.8±1.7	75	92	C	D	2.3±1.2	2.1±1.9	92	92	D	D
P. purpureogenum	1.3±3.3	1.5±4.4	58	58	F	F	1.7±3.0	1.5±3.0	67	75	C	C
P. roseopurpureum	1.3±4.1	2.2±1.3	50	83	F	D	2.3±3.6	1.8±1.1	83	92	D	D
P. rubrum	3.7±1.0	2.7±3.1	92	75	D	C	2.1±2.1	4.0±1.1	83	92	D	D
Trichoderma aureoviride	1.0±0.5	2.2±0.8	42	92	F	D	1.8±3.7	1.5±3.5	33	83	O	D
T. hairzianum	1.4±6.1	4.4±0.5	42	92	F	D	1.7±5.9	4.8±3.5	42	100	F	D
T. koningii	0.9±1.6	1.3±1.1	25	25	O	O	1.0±5.1	1.8±1.8	33	67	O	C
T. pseudokoningii	0.5±1.6	3.1±2.3	25	92	O	D	1.8±2.9	2.8±12	67	100	C	D
T. viride	4.1±3.3	3.4±1.7	75	75	C	C	3.6±2.2	3.1±1.8	100	75	D	C
Scytalidium lignicola	1.6±1.8	0.9±1.3	50	42	F	F	0.4±0.7	0.4±1.7	33	17	O	R
Phoma herbarum	0.9±6.0	1.4±1.4	50	58	F	F	1.6±3.8	2.3±3.4	67	83	C	D

UB and B respectively are unburned and burned sites.

In Frequency class column, the letters, 'D', 'C', 'F', and 'R' denote 'Dominant', 'Common', 'Frequent', 'Occasional' and 'Rare', respectively.

soil respectively in the unburned and burned sites (Fig. 2). The burned site registered significantly higher population of *Azospirillum* in both the years of study (Table 2). The *Azotobactor* population ranged 5.0 to 12.9 x 10^2 and 2.4 to 24.4 x 10^2 /g soil for unburned and burned sites respectively (Fig. 2). Burning enhanced the population of *Azotobactor* significantly during the years 1992-93 and 1993-94 (Table 2). However, during burning months the population declined drastically.

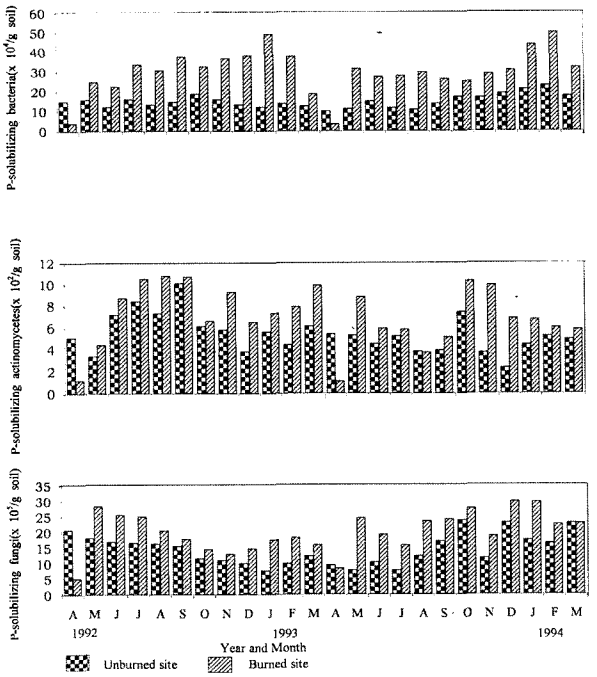

Fig. 2. Changes in the population of P-solubilizing soil microbes as influenced by burning in the study area.

The effect of surface fire on the population of phosphate solubilizing bacteria, actinomycetes and fungi were shown in Fig. 2. The bacterial population increased significantly in the burned site during both the years of observation (Table 2). The actinomycetes and fungal populations were also increased in the burned sites but it is not at significant level. However, for fungi during the second year (1993-94) of observation it was significantly higher. The burning month of April recorded less population of all the three groups of P-solubilizing microbes.

Table 3 gives the list of P-solubilizing fungi (PSF) occurred in the burned and unburned sites during the study period and their mean percentage occurrence, percentage frequency and frequency class. Altogether 36 species of fungi capable of solubilizing insoluble tricalcium phosphate were identified. The propagule density (mean percentage occurrence) of these fungi in the unburned and burned sites varied according to individual species and the year of study. Among the PSF, species such as *Absidia ramosa, Gongronella butlerii, Mortierella spinosa, Mucor racemosus, Rhizopus nigricans, R. stolonifer, R. oryzae, Aspergillus fumigatus, A. nidulans, A. niger, Thielavia terricola* and *Chaetomium lunasporium* were efficient solubilizers exhibiting $Ca_3(PO_4)_2$ clearing zones of more than 1.5 cm width (Table 4). Interestingly, all of them with the exception of *R. stolonifer* and *Chaetomium lunasporium* were highly persistent species as indicated in the frequency class (Table 3).The correlation between certain edapho-climatic factors and N_2-fixing and P-solubilizing microbial populations and nodule number in *Atylosis trinervia* roots were worked out and presented in Table 5. Most of the microbes have significantly positive correlation ($P<0.005$ and $P<0.001$) with various factors such as rainfall, soil moisture, nitrogen and CO_2 evolution. Interestingly, temperature showed negative correlation with microbes in both unburned and burned sites.

Table 4. The colony size and width of the tricalcium phosphate solubilized zones(cm) in the 7 days old pure cultures of phosphate solubilizing fungi

Fungus	Colony size (cm)	Solubilized zone(cm)
Absidia ramosa	3.5-5.0	2.0
Gongronella butlerii	4.3-4.8	2.3
Mortierella spinosa	2.3-3.5	1.7
Mucor racemosus	3.8-4.8	2.9
Rhizopus nigricans	4.0-5.0	3.1
R. stolonifer	4.5-5.0	2.9
Pacilomyces variotii	2.0-2.5	0.9
Chaetomium lunasporium	0.9-1.7	1.9
Neurospora sp.	3.0-4.0	1.3
Thielavia terricola	0.3-0.4	2.3
Alternaria alternata	1.0-1.3	0.8
A. diathicola	1.0-1.3	0.8
Aspergillus awamori	1.5-2.0	0.6
A. flavipes	0.9-1.5	0.7
A. flavus	0.5-1.0	0.7
A. fumigatus	1.0-1.5	1.6
A. nidulans	1.5-2.0	1.8
A. niger	1.0-1.5	2.1
A. terreus	0.5-1.7	1.0
A. versicolor	0.5-1.6	0.9
Cladosporium cladosporioides	1.0-1.5	0.8
Fusarium oxysporum	0.5-1.0	0.6
F. solani	0.5-1.0	0.3
Penecilluum citrium	0.5-0.9	0.4
P. digitatum	0.4-0.9	0.4
P. implicatum	0.5-1.0	0.3
P. purpureogenum	0.5-0.9	0.7
P. roseopurpureum	0.4-0.8	0.6
P. rubrum	0.4-0.8	0.3
Trichoderma aureoviride	0.5-1.0	0.2
T. hairzianum	0.5-1.0	0.4
T. koningii	0.5-1.0	0.3
T. pseudokoningii	0.5-1.0	0.2
T. viride	0.5-1.0	0.3
Scytalidium lignicola	0.7-1.0	1.0
Phoma herbarum	0.2-0.7	0.9

DISCUSSION

It is evident from the data presented in Figs. 1 and 2 and Tables 3 and 4, burning generally favoured soil N_2-fixing and P-

Table 5. Correlation coefficient (r) between certain edapho-climatic factors and N_2 fixing and P-solubilizing microbial populations / Nodule number

Microbes/Nodule number	Site	Edapho-climatic variables								
		Temperature	Rainfall	Soil moisture	pH	N	P	K	Organic matter	CO_2 evolution
Nodule	UB	-0.072	0.533*	0.677**	0.406	0.148	-0.202	0.063	0.293	0.456
number	B	-0.597	0.528*	0.749**	0.419	0.522*	0.264	0.194	0.243	0.310
Rhizobium	UB	-0.535	0.601**	0.665**	-0.105	0.119	0.039	-0.190	-0.178	0.496*
	B	-0.231	0.444	0.687**	0.117	0.326	0.077	0.154	0.084	0.741
Azospirillium	UB	-0.171	0.284	-0.284	-0.320	0.651**	0.175	0.350	0.276	0.034
	B	-0.428	0.096	-0.096	-0.439	0.377	0.342	-0.640	0.319	0.428
Azotobacter	UB	0.012	0.046	0.188	0.312	0.004	0.054	0.218	0.043	0.261
	B	-0.474	0.227	0.685**	-0.010	0.473*	0.384	0.038	0.101	0.617**
P-soubilizing	UB	-0.612	0.033	0.343	-0.586	0.542	0.380	-0.057	-0.501	0.193
bacteria	B	-0.625	-0.122	0.394	-0.205	0.643*	0.581	-0.245	0.289	0.310
P-soubilizing	UB	0.251	0.074	0.213	0.243	0.082	0.141	-0.245	0.143	0.181
actinimycetes	B	-0.209	0.307	0.321	0.041	0.312	0.253	0.060	0.373	0.614*
P-soubilizing	UB	-0.206	0.153	0.351	-0.209	0.517	0.347	-0.048	-0.423	0.398
fungi	B	-0.396	0.196	0.517*	0.075	0.403	0.187	-0.147	0.216	0.640*

UB and B respectively are unburned and burned sites.

* and ** respectively, denotes significant correlation at P<0.005 and P<0.001 levels.

Soil moisture, pH, N, P, K, CO_2 evolution and organic matter data were collected from the source of Senthilkumar, 1995.

solubilizing microbial populations. The stimulating effect of surface fire in the microbial populations might have come directly through increases in the growth rate and metabolic activities of the grassland plants resulting in more root exudates and thereby creating a favorable habitat for the growth and development of these microorganisms (Senthilkumar *et al.* 1995). In soil, the advantage for competitive colonization might be provided in part by substances such as biotin and thiamine exuded by roots (Graham 1963). The production of homoserine at the sites of lateral root emergence has been suggested as a selective stimulant for the growth of *R. leguminosarum* in the rhizosphere of pea seedlings (Egeraat and Van 1975). It may also stated that since organic matter stimulates the growth of microorganisms in the rhizosphere, any management practice (in this case, fire) increases the total C accumulation and in turn it will also increases the size and activities of the soil microbial biomass(Lynch and Panting 1980). Confirming this, the content of organic matter positively correlated with all the enumerated microbes in burned site when compared with unburned site (Table 5). *Azospirillum*, the aerobic nitrogen fixing bacterium, is commonly associated with rhizosphere of certain tropical grasses was increased its population in burned sites. The foregoing account clearly establishes the fact that the populations of N_2-fixing microorganisms are determined by the extent of root development by the plant community which in turn enhanced by fire(Senthilkumar *et al.* 1998a).

Azotobactor is obligately aerobic, free-living nitrogen fixing bacterium which may require several weeks or months to establish contact with plant roots (Curl and Truelove 1986). Similarly, in the present study, its population was lower than those of *Rhizobium* and *Azospitillum*. Strzelczyk(1961) attempted to correlate the low numbers of *Azotobactor* in both rhizosphere and root-free soils with antagonism by other bacteria and actinomycetes. Monocots like wheat produced toxic zones of inhibition against *Azotobactor* in standard antibiosis tests than were found in root free soil.

A promotion of nodulation in *Atylosia trinervia* was observed in the post-fire community during the second year of observation. This may be attributed to higher soil temperature in the burned site resulted from the lack of shading canopy and increased absorption of solar radiation by the blackened soil surface.

Several works have stated that after rain, the population of post - fire microorganisms increased rapidly and exceeds the levels in unburned control plots (Wicklow and Zak 1979). Indeed, the Kundah grasslands received adequate rainfall for microbial growth following wild-fires especially during the second year of study (Table 1). The microbes in turn maintain the productivity of the plant community at an optimal level by the way of increased nitrogen fixation by N_2- fixing microbes and made phosphorus available by the increased population of P-solubilizing microbes in the post-fire community (Figs.1 and 2).

All microbial populations were found to be drastically decreased immediately after fire in the present study (Figs. 1 and 2). Similarly, the CO_2 evolution through soil microbial respiration was decreased suddenly during burning months (April of 1992 and 1993) in the surface layer. Nevertheless, the bottom layer (10-

20cm) showed no major change in the population structure of microorganisms (Senthilkumar *et al.* 1997). Renbuss *et al.* (1973) pointed out that this may be attributed to the direct impact of heat by fire. The mineral horizons usually are well insulated from the heating effect of fire and soil organisms in the deep layers may hardly be disturbed by burning.

Phosphorus occurs as a constituent of both organic and inorganic compounds in soil and the microbial communities regulate the phosphorus cycle through heterotrophic mineralization of organic phosphorus compounds as well as through solubilization of aluminium, iron and calcium phosphates (Alexander 1977). In the present study, immediately after burning the amounts of phosphorus in the surface soil declined sharply. However, it ultimately seems to augment the available P pool considerably. Further, the higher population of P - solubilizing bacteria, actinomycetes and fungi in the post-fire community may result in increased P-solubilization (Fig. 2).

Among the 36 species of P-solubilizing fungi recorded from the study site (Table 3), the most efficient solubilizers of tricalcium phosphate were the species belonging to the order in Mucorales followed by *Aspergilli, Theilavia terricola* and *Chaetomium lunasporium*. All these fungi have the characteristics of opportunistic "cellulose degrading fungi" and may derive nutrients from sugars, starches and amino acids which are leached from the organic matter. The study of Craven and Hayasaka (1982) have shown that the carbon and energy source are essential for solubilization of mineral phosphates. A number of possible carbon and energy sources including amino acids and glucose are found in rhizosphere soils especially of burned sites. Amino acids are found in root exudates and glucose may result from microbial cellulolytic activity, microbial breakdown of starch and complex sugars or root exudates (Senthilkumar 1995).

The successional pattern of mycoflora associated with litter decompostition in tropical grasslands was given elsewhere (Senthilkumar *et al.* 1992,1993 a,b). Meiklejohn (1955) showed that in one instance a species of *Penecillium* was replaced by a species of *Aspergillus* and Jalaludin (1969) reported that the species of *Trichoderma* and *Penecillium* were the first to colonize in burned ground. The results suggested that in tropical grasslands, fungal succession seems to be same by Zygomycotina occupied primitive position followed by Hyphomycetes consisting, dematiaceous and moniliaceous groups.

The contents of moisture, N,P,K and organic matter and CO_2 evolution in soil and rainfall were positively correlated with all studied microbial populations in the grasslands of the soils of study area (Table 5). Under the conditions of high temperature with low soil moisture followed by wetting, increased the root exudation which in turn enhanced the population of microorganisms (Curl and Truelove 1986).

To our knowledge this is the preliminary study concerning with the dynamics of the population of various beneficial microorganisms in natural grasslands where the annual summer fire has influences, and altogether the results suggested that surface fire played a positive role in the population increase and hence the activity of microorganisms. Further more, the rainfall immediately after burning is considered to be the major factor for the increase of beneficial microorganisms. Therefore, it is suggested that prescribed burning can be used as a tool to design the management strategy for Kundha grasslands.

ACKNOWLEDGEMENTS

This paper was supported by Wonkwang University in 2002.

LITERATURE CITED

Alexander, M.1977. Introduction to Soil Microbiology. 3rd edition, 465 Wiley, New York. p.465.

Craven, P. A. and S. S. Hayasaka. 1982. Inorganic phosphate solubilization by rhizosphere bacteria in a *Zostera marina* community. Canadian Journal of Microbiology 28: 605-610.

Curl, E. A. and B.Truelove. 1986. The Rhizosphere. Springer-Verlag, Berlin.

Graham, P. H. 1963. Antigenic affinities of root-nodule bacteria of legumes. Journal of Microbiol Serology 29: 281-291.

Jalaludin, M. 1969. Microorganic colonization of forest soil after burning. Plant and Soil 30:150-152.

Jensen, V. 1968. The Plate Count Method. *In* T.R.G. Grey and D. Parkinson (eds.), The Ecology of Soil Bacteria: An International symposium. Liverpool University press, Liverpool. pp. 158-170.

Lynch, J. M. and L. M. Panting. 1980. Cultivation and the soil biomass. Soil Biology and Biochemistry 12:29-33.

Meiklejohn, J.1955. The effect of bush burning on microflora of a Kenya upland soil. Journal of Soil Science 6:111 - 118.

Moore, R. M. and E. F. Biddescombe. 1964. The effects of grazing on grasslands. *In* C. Barnard (ed.), Grasses and Grasslands. MacMillan Publishing Company, London. pp. 221-235.

Renbuss, M. A., G. A. Chilvers and L. D. Pryor. 1973. Microbiology of an ash bed. Proceedings of Linnean Society of New South Wales 97: 302-311.

Senthilkumar, K. 1995. Effect of surface fire on the dynamics of beneficial microbial populations in a natural grassland ecosystem, southern India. Ph.D. Thesis, Bharathiar University, Coimbatore, India.

Senthilkumar, K., K. Udaiyan and S. Manian. 1992. Rate of litter decomposition in a tropical grassland dominated by *Cymbopogon caesius* in southern India. Tropical Crasslands 26: 235-242.

Senthilkumar, K., K. Udaiyan and S. Manian. 1993a. Succ-cessional pattern of mycoflora associated with litter degradation in a *Cymbopogon caesius* dominated tropical grasslands. Tropical Grasslands 27:121-127.

Senthilkumar, K., S. Manian and K. Udaiyan. 1993b. Mycoflora associated with litter decomposition in a *Cymbopogon caesius* dominated tropical grassland soil. Journal of Swamy Botanical Club 10:91-95.

Senthilkumar, K., S. Manian, K. Udaiyan and V. Sugavanam. 1995. Effect of burning on soil nutrient status and abundance of VA - mycorrizal fungi in a savannah type grassland ecosystem in south India. Tropics 4: 173-186.

Senthilkumar, K., S. Manian and K. Udaiyan. 1997. Effect of burning on soil enzyme activities in natural grasslands in southern India. Ecological Research 12: 21-25.

Strzelczyk, E. 1961. Studies on the interactions of plants and free-living nitrogen-fixing microorganisms. II. Development of antagonists of *Azotobactor* in the rhizosphere of plants at different stages of growth in two soils. Canadian Journal of Microbiology 7: 507-513.

Subbarao, N. S. 1986. Soil Microorganisms and Plant Growth. Oxford and IBH Publishing Co., New Delhi, India. 380p.

Sundararao, W. V. B. and M. K. Sinha. 1986. Phosphate dissolving organisms in the soil and rhizosphere. Indian Journal of Agricultural Science 33: 272-278.

Thomas, A. S. 1960. Proceedings of IXth International Grassland Congress, Reading, pp.405-407.

Wicklow, D. T. and J. C. Zak.1979. Ascospore germination of carbonicolous ascomycetes in fungistatis soils: An ecological interpretation. Mycologia 71: 238-242.

(*Received May 14, 2002, Accepted July 8, 2002*)