Indian Forester, 143 (8) : 759-766, 2017
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

LIFE AFTER FIRE FOR UNDERSTORY PLANT COMMUNITY IN SUBTROPICAL CHIR PINE FOREST OF GARHWAL HIMALAYA

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ABSTRACT

Fire is believed to act as an environmental cue for regeneration of plant community in majority of the forest ecosystems encounter natural fire. However, the positive role of anthropogenic fire on regeneration ecology of understory vegetation in chir pine forest is doubtful. In this study, the effect of anthropogenic fire on regeneration was compared between burned and unburned sites of the Chir pine forest in Garhwal Himalaya. The result indicated that forest fire has no considerable impact on regeneration. Species richness and seedling density were higher in burned and unburned sites respectively, but both of these trends were non-significant. Shannon-Wiener Diversity index (H') and Evenness (J') were high in burned as compared to unburned sites. Plant species that were regenerated through resprouting after forest fire includes ethnomedicinal species, grasses/fodder species, and invasive species. However, the majority of species in burned sites were regenerated through seeds. It is concluded that fire can act as an important disturbance factor to some extent, but it failed to enhance significantly the regeneration potential of understory vegetation. Thus, the finding contradicts the traditional beliefs of local communities which perceived grass/fodder plants regenerate much vigorously after an intentional forest fire.

Key words: Forest fires, Chir pine, Species richness, Resprout, Vegetative propagules.

Introduction

Chir pine is a fire-resistant tree species, yet pine forests are highly vulnerable to the repeated fires (Gupta *et al*., 2009). The fire and Chir Pine forests hypothesis is a generally accepted perspective as disturbance ecology for the sub-tropical pine forest in Central Himalaya, India. Fire is postulated to have been a relatively constant disturbance process historically in old-growth temperate forests (McEwan *et al*., 2014) and a major ecological force in shaping the Mediterranean vegetation (Ferrandis *et al*., 1999) where fire is natural phenomena but in Chir pine forest it has been associated with intentional ignitions from natives during summer season to derive fodder and other produce for their subsistence living from the surrounding Chir pine forests. As pine forest is having a relatively thin canopy which helps light to penetrate ground level and provide a congenial environment for the growth of understory vegetation comprising grasses, sedges, legumes and other non-leguminous species (Semwal and Mehta, 1996). In Indian Himalayan region, it is a common people's perception that fire promotes regeneration and growth of the majority of grasses and fodder species if the fire burns the ground litter layer and succeeded by moderate rainfall in pre-monsoon season. Although some studies have been carried out on fire ecology in Chir pine forests to assess post-fire plant composition, however, we lack enough empirical evidence about fire impact on regeneration ecology of the understory vegetation in Chir pine forests especially their mode of regeneration whether they are seedling (seed) origin or resprouted from vegetative propagules after a forest fire. This study is an attempt to fill this gap.

As Semwal and Mehta (1996) reported the majority of fire in chir pine forest is of surface fire in nature, which burns all litter layer (such as dry leaves, twigs, grasses, etc) that also kills existing understory vegetation. Understory plant communities play critical roles in maintaining key ecosystem processes (Hart and Chen, 2006; Venier and Pearce, 2007). After the outbreak of fire, understory gaps are formed thereby resulting in the regeneration of other associated understory species due to sufficient light, altered temperature regime, changed in the soil physicochemical properties and the possible role that smoke water play in promoting the understory plant communities, that may resprout from roots or rhizomes (Archibold, 1979; Carroll and Bliss, 1982; Whittle *et al*., 1998), germinate from seeds persisting in the soil seed bank (Moore and Wein, 1977; Morgan and

Contrary to people's perception about the positive impact of forest fire on vigorous regeneration of grasses/fodder species in chir pine forest, present study did not find any empirical evidence to support this perception.

Neuenschwander, 1988), established from seeds carried in from off-site (Qi and Scarratt, 1998) or encroach from surrounding areas (Hautala *et al*., 2001). In contrast, the unburned sites maintain low light; have constant temperature, more thickness of litter layer and probably no role of smoke water thereby suppressing the regeneration from seeds already persisting in the soil seed bank or propagule banks due to high competition for resources within and/or among species. Moreover, aerial seed bank has a role in vegetation recovery in the burned sites, especially for species with leguminous or serotinous fruits as high temperature during fire helps the opening of the pods and serotinous fruits if the plant is not fully destroyed but this phenomenon is lacking in unburned sites.

The relative importance of these different regeneration mechanisms differ from species to species and will likely be influenced by disturbance severity, stand age and soil properties (Pinno and Errington, 2016). High burn severities can also change the composition of surviving vegetation from which resprouting is possible after reducing or eliminating stored seed banks in the organic material where most seeds are found and by eliminating competition (Roberts, 2004). Soil properties may also impact understory plant regeneration after disturbance to a greater degree than tree regeneration, as understory plant species are more sensitive to changes in soil chemical and physical properties than are tree species growing on the same sites (Pinno and Errington, 2016). However, how these factors interact with each other and how they influence the plant community in Chir pine forests after the fire is not clear.

We studied regeneration of understory plant community of subtropical Chir pine forest of Garhwal Himalaya in response to fire to gain a better understanding: how the plant communities respond to a disturbance after a forest fire? The specific questions we asked are 1) do forest fire have an impact on understory plant community of Chir pine forest?, and 2) which of the regeneration pattern (seedling *vs.* resprouting of propagules) play an active role in vegetation recovery after a forest fire in burned sites?

Material and Methods

Study area

The study was conducted in Central Himalayan low altitude subtropical Chir pine forest of Srinagar-Garhwal (Civil Soyam) Range (30°12.603'N latitude and 78°47.571'E longitude) of the Alaknanda River valley in Pauri Garhwal district, Uttarakhand. This region is considered as severely affected by frequent forest fire. The climate at the study site is monsoonal (hot humid subtropical) and can be divided into summer, rainy and winter seasons (Kumar *et al*., 2013). Precipitation at Srinagar is weakly bimodal, with a small peak of 100 mm during January and the majority of total rainfall occurring during the Indian monsoon season from late June through September (Bhandari *et al*., 2000). The site is located on a steep (30° to 45°) generally north-facing slope and ridge. Elevation in the study site is 1020 m amsl. The soil of the area is well drained and acidic in nature (Kumar *et al*., 2013).

Data collection and analysis for post-fire regeneration

Eight permanent plots of 1x1m were laid out randomly in May 2012 (4 each in burned and unburned sites). These plots were established soon after the fire and before the onset of the rainy season. The permanent plots were visited every month starting from mid-June 2012 to mid-May 2013 in order to assess the damage caused by forest fire to understory vegetation and to monitor regeneration pattern by visually inspecting the newly emerged seedlings either from seeds or resprouted from vegetative propagules. Monitoring of regeneration through vegetative parts for evaluating propagule banks was done in burned permanent plots only. Evaluation of resprouted plants was done for initial five months i.e. from June 2012 to October 2012 only as the majority of plants obtained the full maturity by that time and thereafter become difficult to distinguish their mode of regeneration. However, monitoring of all the plants found on the permanent plots of burned site was continued for 12 months until mid-May 2013. For comparative analysis between burned and unburned sites, all the plants (species and individuals) that have been found on the permanent plots of the unburned site was also recorded for 12 months. The Shannon-Wiener Diversity Index (Shannon and Wiener, 1963) was used to determine species diversity and evenness (J') (Pielou, 1966). The botanical nomenclature of plant species follows that of Gaur (1999) and APG III (2009).

Statistical analysis

Mean and standard errors were calculated for species number and density of plants based on emerged seedlings present in permanent plots of burned and unburned sites. Data for species number were square transformed for analysis to fulfil the assumption of normality and homogeneity. The box plots showing median, quartiles, outliers and extremes were generated to show the relationship between variables. The Shapiro-Wilk test of normality and Levene's test of homogeneity revealed that transformations were unsuccessful in correcting heteroscedasticity for some of the data sets. Thus, means were compared either by student t-test and/or one-way ANOVA (if data met assumption of normality and homogeneity of variance) or by Welch's F test (Welch's ANOVA, if data violated the assumption of normality and homogeneity of variance, *sensu* Phartyal *et al*., 2014) followed either by the Tukey posthoc tests (if equal variances assumed) or the Games–Howell posthoc tests (if equal variances not assumed) (P = 0.05) using IBM SPSS Statistics 21. Further to estimate the effects of month and site on species number and density data were subjected to two-way ANOVA using univariate general linear model (GLM).

Results

Species composition

A total of 1552 seedlings emerged from the permanent plots of burned and unburned sites during the entire study period of 12 months. Of these, 42% (646 seedlings) were recorded from the burned sites and 58% (906 seedlings) were recorded from the unburned sites. Altogether, 53 species were recorded during the entire study period. Out of these, 39 species (35 identified: 17 herbs, 9 grasses, 7 shrubs, 1 tree, 1 climber and 4 unidentified species) were recorded from the burned sites and 36 species (22 herbs, 8 grass, 5 shrubs and 1 climber) from the unburned sites with 22 species (10 herbs, 7 grasses, 4 shrubs and 1 climber) in common (Fig. 1).

Mean species number and density

The statistical test of mean species number per month revealed that there was no significant difference (p = 0.99) in burned and unburned sites (Fig. 2). A similar pattern was also found for mean density per month for both burned and unburned sites (p = 0.130) (Fig. 3).

The month wise mean species number (represented by seedling emergence) in both burned and unburned sites revealed that highest number of species emerged in September 2012, while the lowest was recorded in January 2013 and April 2013 (Welch's $F_{11,\ 32.59}$ = 33.05, $p < 0.001$) (Fig. 4). Similarly, the month wise density was higher in September 2012 and lowest in January 2013 and April 2013 (Welch's $F_{11,\ 31.82}$ = 10.92, $p < 0.001$) (Fig. 5).

Mean species number in burned sites revealed that highest number of species emerged in September 2012 while the lowest was recorded in January 2013 (0.50) and February 2013 (0.50) (F = 19.51, df = 11, $p < 0.001$) (Fig. 6a). However, the month wise mean species number in unburned sites were almost same from July to October 2012 ranging from 4.75 to 6.5 while the lowest mean species number was recorded in April 2013 (0.50) and January 2013 (0.25) (F = 5.70, df = 11, $p < 0.001$) (Fig. 6b).

The month wise mean density of plants in burned

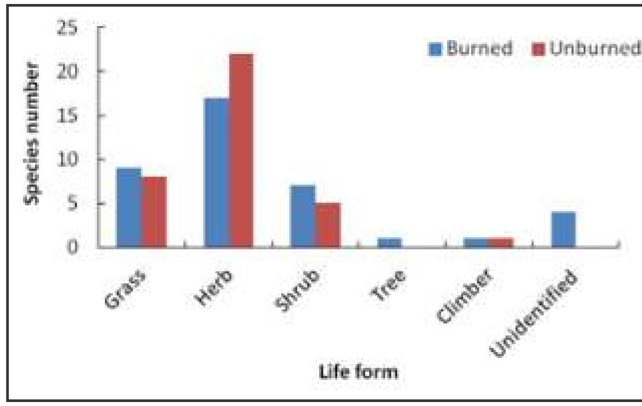

Fig. 1: Species number and life form pattern of the identified plant species found in the permanent plots of burned and unburned sites.

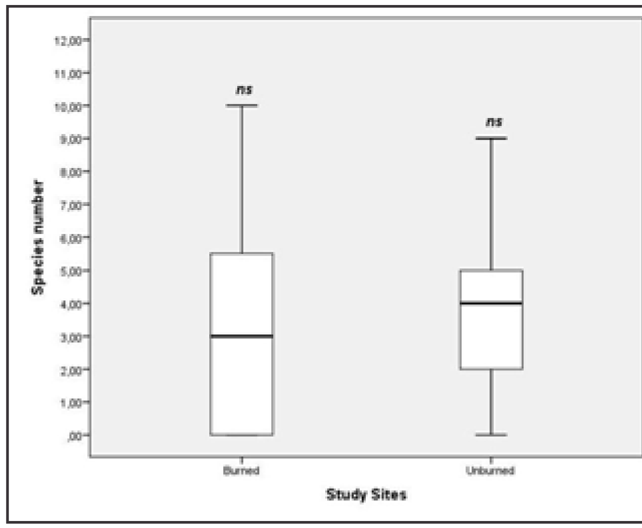

Fig. 2: Box plot showing median and quartiles of species number for both burned and unburned sites. Letter '*ns*' represent subset with non-significant (t = -0.014, df = 94, p = 0.99) differences.

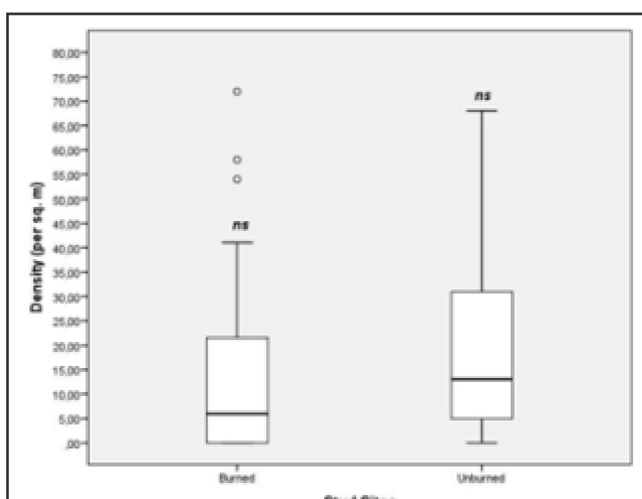

Fig. 3: Box plot showing median, quartiles and outliers (o) of density for both burned and unburned sites. Letter '*ns*' represent subset with non-significant (t = -1.526, df = 94, p = 0.130) differences.

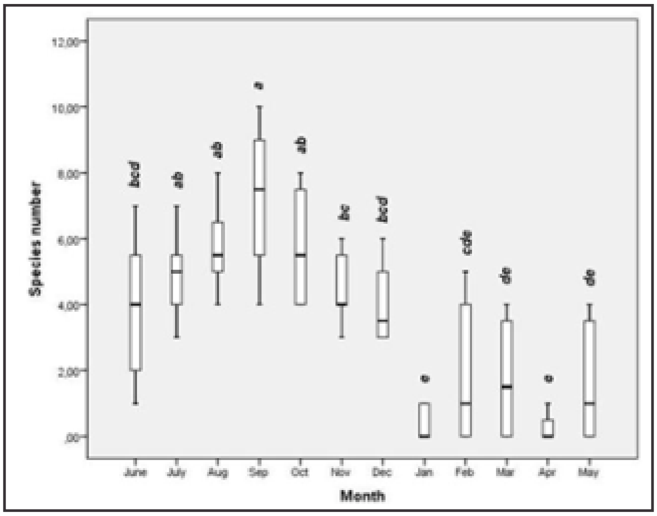

Fig. 4: Box plot showing median and quartiles of month-wise species number present in permanent plots of burned and unburned sites. Letters represent subsets with significant (Welch's $F_{11, 32.59} = 33.05$, $p < 0.001$) differences.

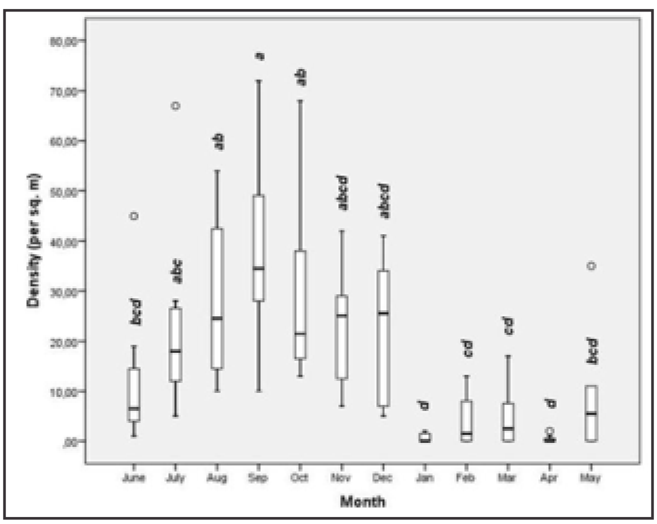

Fig. 5: Box plot showing median, quartiles and outliers (o) of the month-wise density of plants present in permanent plots of burned and unburned sites. Letters represent subsets with significant (Welch's $F_{11, 31.82} = 10.92$, $p < 0.001$) differences.

sites was highest in September 2012 (49.0 m^{-2}) while the lowest mean density were recorded in the month of January and February, i.e. 0.75 m^{-2} (Welch's $F_{9, 11.76} = 10.12$, $p < 0.001$) (Fig. 7a). Whereas, in unburned sites, highest seedling density was recorded in October 2012 (39.5 m^{-2}) and lowest were recorded in April 2013 (0.75 m^{-2}) and January 2013 (0.50 m^{-2}) ($F_{11, 13.67} = 5.57$, $p < 0.002$) (Fig. 7b).

Effects of interaction of month and site on species number and density

The two-way ANOVA results reveal that the factor 'month' and the interactions (between month and site) had significant effects on species number (Table 1). Based on high F-values, factors that most strongly influenced species number was 'month' ($F = 19.41$). However, in the case of density both factors (month and site) had a significant effect with the highest influence of 'month' ($F = 8.08$) (Table 1).

Diversity and evenness of understory plant communities

The Shannon-Wiener index (H') showed high diversity in the month of September 2012 (2.17) and the least diversity in December 2012 and January 2013 (0.64 each) in the burned sites. Similarly, in unburned sites high diversity was recorded in September 2012 (2.21), and least diversity in January 2013 (0.00) (Table 2). In contrast, high Evenness (J') was recorded from January to March 2013 (0.92 each) and the least in April and May 2013 (0.00 each) in the burned sites. However, in unburned sites highest evenness was recorded in May 2013 (0.95) and least in the January 2013 (0.00) (Table 2).

Regeneration pattern (through seed origin vs. re-sprouted) in burned sites

During the entire observation period, a total of 473 seedlings of 30 different species had emerged. Out of this, 445 were of seedling origin and 28 were re-sprouted individuals (Table 3). Immediately after forest fire (in June

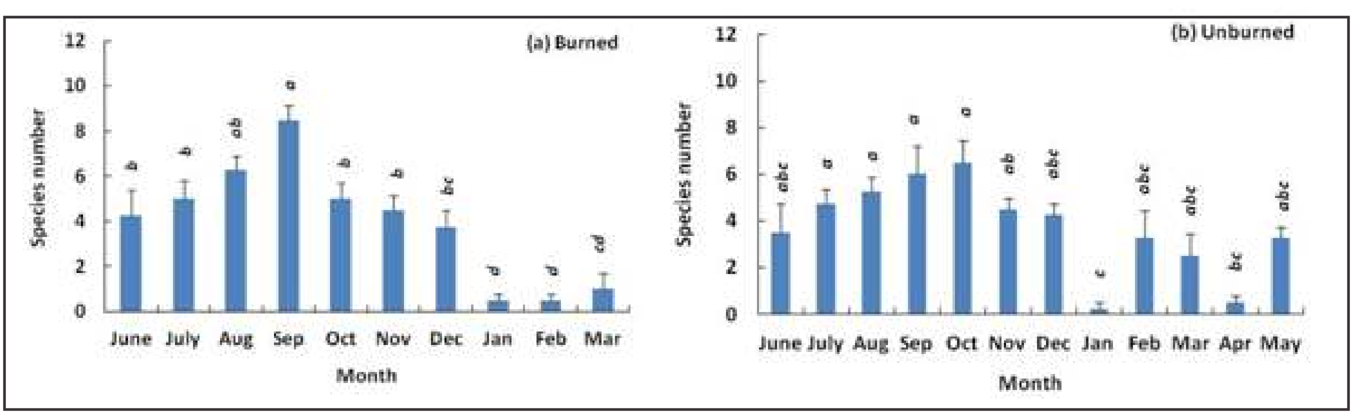

Fig. 6: Mean species number based on emerged seedlings in permanent plots of a) burned and b) unburned sites. Letters represent subsets for a) burned ($F = 19.51$, $df = 11$, $p < 0.001$) and b) unburned ($F = 5.70$, $df = 11$, $p < 0.001$) with significant difference.

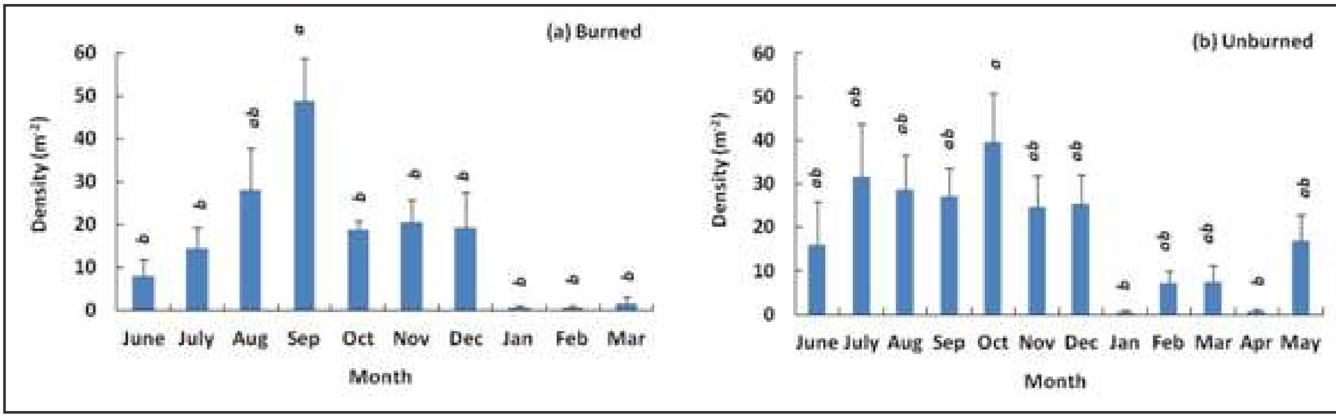

Fig. 7: Mean density of plants based on emerged seedlings in permanent plots of a) burned and b) unburned sites. Letters represent subsets for a) burned (Welch's $F_{9,11.76} = 10.12$, $p < 0.001$) and b) unburned ($F_{11,13.67} = 5.57$, $p < 0.002$) with significant difference.

Table 1: Results from two-way ANOVA for effects of month and site on species number and density. (Bold values indicate statistical significance).

Parameter	Variation explained by the model (R^2)	Factor	df	F-Value	P-Value
Species Number	0.771	Month	11	19.418	<0.001
		Site	1	2.151	0.147
		Month × Site	11	2.449	0.012
Density (m^{-2})	0.604	Month	11	8.082	<0.001
		Site	1	4.402	0.039
		Month × Site	11	1.516	0.145

Table 2: Month-wise Species richness (SR), Shannon-Wiener Diversity Index (H') and Evenness (J') of burned and unburned sites of the understory plant communities.

Month	Species richness (SR)		Shannon-Wiener Diversity Index (H')		Evenness (J')	
	Burned	Unburned	Burned	Unburned	Burned	Unburned
Jun 2012	11	9	2.13	1.67	0.89	0.76
Jul 2012	12	11	2.00	1.53	0.80	0.64
Aug 2012	16	10	1.94	1.89	0.70	0.82
Sep 2012	17	15	2.17	2.21	0.77	0.81
Oct 2012	15	16	1.95	2.19	0.72	0.79
Nov 2012	15	10	1.87	1.81	0.69	0.79
Dec 2012	13	9	2.05	1.66	0.80	0.76
Jan 2013	2	1	0.64	0.00	0.92	0.00
Feb 2013	2	9	0.64	1.88	0.92	0.86
Mar 2013	4	7	1.28	1.63	0.92	0.84
Apr 2013	-*	2	-*	0.64	-*	0.92
May 2013	-*	5	-*	1.52	-*	0.95

'*' represents data that are not available due to repeated burning in the month of April and May 2013

2012), six species i.e. *Chrysopogon fulvus*, *Imperata cylindrica*, *Barleria cristata*, *Desmodium gangeticum*, *Carissa carandas* (Fig. 8) and *Cyperus neveus* were found re-sprouted. *Cessampelos pareira* and *Eupatorium adenophorum* re-sprouted in the month of July 2012 and August 2012 respectively (Table 3).

Discussion

The understory vegetation in chir pine forest was dominated by herbaceous and grass species in both burned and unburned sites. Based on present study it can be concluded that forest fire has no considerable impact on regeneration potential of understory vegetation in chir pine forest. Although more species emerged in burned than the unburned sites but the increase in species number is not statistically significant. More species after fire have also been reported by Rikhari and Palni (1999) in oak mixed broad-leaved forests of Central Himalaya and in chir pine forests of northwest Himalaya (Anita, 2001). The density of plants in unburned sites was higher than the

Fig. 8: Post fire re-sprouting of *Carissa carandas* in burned sites.

burned sites. The possible reason for the lower density in burned site may be due to the fact that fire might destroy the majority of viable seeds persisting especially at the surface and in the upper layer of the soil seed bank that might otherwise are capable of colonizing the site. Ilyas and Khan (2005) also reported high mortality due to frequent fire which is responsible for killing the plants.

The Shannon-Wiener Diversity index (H') and evenness (J') showed no specific pattern with the advancement of growing season. However, the favorable growth conditions during the mid-season may have contributed to higher diversity. Shannon-Wiener Diversity index (H') and Evenness (J') were high in burned sites as compared to unburned sites. Similar trends of higher diversity index in burned than unburned sites were also reported by Sawarker *et al*. (1986); Sundriyal *et al*. (1987); Rikhari and Palni (1999) and Gupta *et al*. (2009).

There are three sets of species that regenerate through resprouting after a forest fire. These are ethnomedicinal plants (*Barleria cristata* and *Carissa*

Table 3: Post-fire regeneration pattern (R= re-sprouted and S= seed origin) represented by emerged seedlings in burned sites. Symbol "*" represents re-sprouted individuals after a forest fire. Data was collected for only five months (see Material and methods).

Family	Species	Life form	Jun '12		Jul '12		Aug'12		Sep '12		Oct'12	
			R*	S	R	S	R	S	R	S	R	S
Acanthaceae	*Barleria cristata*	Herb	3*			2		1		1		1
	Justicia simplex	Herb								15		10
Anacardiaceae	*Rhus parviflora*	Shrub								1		
Apocynaceae	*Carissa carandas*	Shrub	1*									
Asparagaceae	*Asparagus curriculus*	Shrub		1		1		1				
Asteraceae	*Cirsium vulgare*	Herb				1						
	Erigeron spp.	Herb						1				
	Eupatorium adenophorum	Shrub					1*					1
Commelinaceae	*Cyanotis cristata*	Grass						32		34		
Cyperaceae	*Cyperus neveus*	Grass	1*			3						1
	Cyperus spp.	Grass		2		2						
Euphorbiaceae	*Euphorbia hirta*	Herb										1
	Melotus phillipensis	Tree				1						
	Phyllanthus ninuri	Herb						36		42		33
	Euphorbia emodi	Herb								9		
Fabaceae	*Desmodium gangeticum*	Shrub	9*							1		1
	Crotalaria albida	Herb						1				
Minispermaceae	*Cessampelos pareira*	Climber			4*			3				
Orchidaceae	*Habenaria marginata*	Herb								2		3
Oxalidaceae	*Oxalis corniculata*	Herb		2		7		10		1		
Poaceae	*Chrysopogon fulvus*	Grass	5*			2		2		2		
	Imperata cylindrica	Grass	4*			20		10		6		2
	Arundinella nepalensis	Grass		1		12		3		9		
	Athraxon spp.	Grass		3		3		3		2		1
	Setaria pumila	Grass								16		9
	Mnesithea granularis	Grass								8		4
Polygalaceae	*Polygala chinensis*	Herb								1		1
Scrophulariaceae	*Lindernia crustaceae*	Herb								46		4
	Unidentified spp. 1							1				
	Unidentified spp. 2							7				3

carandas), grasses and fodder species (*Chrysopogon fulvus*, *Imperata cylindrica, Cyperus neveus, Desmodium gangeticum,* etc.) important for feeding livestock, and invasive plant species (*Eupatorium adenophorum*). Invasive species has always a more competitive edge over native species to tolerate moderate to heavy disturbance stress. It was also reported that due to genetic differentiation and plasticity in seed size and germination traits in different populations of *E. adenophorum*, it helps this species acclimatized to different elevations and facilitating its invasiveness (Li and Feng, 2009). However, the majority of species in burned sites were regenerated through seeds. Lack of any considerable role by forest fire as an environmental cue to promote regeneration of understory vegetation indicates that an anthropogenic forest fire in Himalayan Chir pine forest has no ecological role to play like natural forest fire played in shaping the present vegetation of Australian heathland, tropical savannas and Mediterranean forest of other parts of the world that rely on forest fire for their regeneration ecology. Species growing in these ecosystems develop various special functional traits, namely thick fire resistant bark, germinating bud embedded in fire resistant foliage or embedded under the soil surface, a higher rate of flower and seed production, winged seed, serotinous fruiting bodies and lignotubers to survive the recurring forest fire (Zedler, 1995). These kinds of plant functional traits are generally lacking in understory plant community in chir pine forest, which further support that intentional man-made forest fire has no positive role to play in regeneration and shaping of understory plant communities in this region. However, it might be possible that species that resprouts after fire are resistant to fire in their adult life-stage and others which are killed or burned completely by fire may have other life-stage (like seeds) to tolerate fire damage and compensate adult plants sensitivity to fire.

Conclusion

Contrary to people's perception about positive impact of forest fire on vigorous regeneration of grasses or fodder species in understory chir pine forest, there is no empirical evidence found in present study that indicates forest fire can have a significant impact on regeneration potential of understory vegetation. This contradicts the traditional beliefs of local communities about positive role of intentional forest fire.

Acknowledgment

Authors are thankful to University Grants Commission (UGC), New Delhi for the financial support provided under a Major Research Project to SSP {39-925/2010(SR)}.

गढ़वाल हिमालय के उप उष्णकटिबंधीय चीड़ पाइन वन में अधोवितान पादप समुदाय के लिए आग के बाद जीवन

बाबीमूर कोनसम, श्याम सिंह फर्त्याल, मुनीष कुमार एवं नागेन्द्र प्रसाद टोडरिया

सारांश

ऐसा विश्वास किया जाता है कि आग ऐसे अधिकांश वन पारितंत्रों में पादप समुदायों के पुनर्जनन हेतु एक पर्यावरणीय संकेत के रूप में कार्य करती है, जो प्राकृतिक आग का सामना करते है। तथापि, चीड़ पाइन में अधोवितान वनस्पति की पुनर्जनन पारिस्थितिकी पर मानवोद्भवी आग की सकारात्मक भूमिका संदेहजनक है। इस अध्ययन में पुनर्जनन पर मानवोद्भवी आग के प्रभाव की तुलना गढ़वाल हिमालय की चीड़ पाइन वन के जले और बिना जले स्थलों के बीच की गई। परिणामों ने दर्शाया कि वनाग्नि का पुनर्जनन पर कोई खास प्रभाव नही है। प्रजाति समृद्धता और पौध घनत्व क्रमशः जले और बिना जले स्थलों में उच्च था। किन्तु ये दोनों रूझान गैर-महत्वपूर्ण थे। शैनॉन वीनीयर विविधता तालिका (एच') एवं समानता (जे') बिना जले स्थलों की तुलना में जले स्थलों में उच्च थी। वनाग्नि के बाद पुनरअंकुरण के जरिए पुनर्जनित पादप प्रजातियों में मानव औषधीय प्रजातियां, घास/चारा प्रजातियां और आक्रामक प्रजातियां शामिल हैं। तथापि, जले स्थलों में अधिकांश प्रजातियां बीजों के जरिए पुनर्जनित थी। यह निष्कर्ष निकाला गया कि आग कुछ सीमा तक एक महत्वपूर्ण विक्षोभ कारक के रूप में कार्य कर सकती है लेकिन यह अधोवितान वनस्पति की पुनर्जनन क्षमता को महत्वपूर्ण रूप से बढ़ाने में असफल रही है। अतः निष्कर्ष स्थानीय समुदाओं के इस पारम्परिक विश्वास का खण्डन करते हैं कि जानबूझकर लगाई गई वनाग्नि के बाद घास/चारा पादपों का पुनर्जनन अधिक प्रचुर मात्रा में होता है।

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