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Effect of forest fire on soil properties and natural regeneration in Chirpine (*Pinus roxburghii*) forests of Himachal Pradesh, India

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Abstract. *Sharma Y, Gupta T, Gupta RK, Sharma PP. 2023. Effect of forest fire on soil properties and natural regeneration in Chirpine (*Pinus roxburghii*) forests of Himachal Pradesh, India. Asian J For 7: 125-132.* Forest fires have a significant impact on the physical environment, such as land cover, land use, forest ecosystems, and biodiversity. The present study was carried out to quantify the effect of forest fire on soil properties and natural regeneration of Chirpine (*Pinus roxburghii* Sargent) forests in Himachal Pradesh, India. Data collection was conducted at six different sites in three forest divisions, namely Solan Forest Division, Hamirpur Forest Division and Dehra Forest Division during the year 2020. Burnt and unburnt forests were selected at each site and were compared with each other to study the effect of fire. The results reported that electrical conductivity, pH, available nitrogen, available phosphorus, available potassium were higher in burnt forests when compared to unburnt forests of the studied sites whereas organic carbon (%) was lower in burnt forests as compared to unburnt forests. Seedling density of trees was found higher in burnt forests whereas sapling density was found higher in unburnt forests. This indicates that fire is good for regeneration but frequent fires can be detrimental for the survival of seedlings. Frequent forest fires need to be prevented and that can be done mainly by social awareness and developing strategies for use of pine needles in farming practices and commercial use in paper, pulp and wood industries.

Keywords: Burnt, forest fire, *Pinus roxburghii*, soil, unburnt

INTRODUCTION

India is one of the world's biodiversity hotspots, both in terms of fauna and flora. Forests are regarded as one of the most important terrestrial ecosystems, providing habitat for biodiversity as well as variety of goods and services to rural communities. These vital resources are constantly degraded and exploited as a result of anthropogenic activities and changes in climatic conditions (Tata et al. 2018; Pokhriyal et al. 2020). The Indian Himalayan Region (IHR) has a rich and diverse forested area, and thus forests are now regarded as a major repository of nature that must be conserved and managed for posterity, rather than being regarded solely as an important source of revenue (Negi et al. 2012).

Himachal Pradesh, located in the heart of the Himalayas, has abundant forest resources and ecologically significant geographical areas. These forests are vulnerable to forest fires for a variety of biotic and geographical reasons. The severity of the problem can be gauged by the 1995 forest fires in the state, which resulted in a 1750 million dollar loss (FSI 2009). The Himalayas are home to the Indian Pines, which constitute an economically important community of species, provide valuable natural resources and make a major contribution to the country's local and industrial economy. Lower Himalaya, which is located between latitudes 26°N to 36°N and longitudes 71°E to 93°E (Ghildiyal et al. 2009), is home of chirpine (*Pinus roxburghii* Sargent). In Himachal Pradesh, 10.40% of forest cover is under forest type 9/C1a (Lower or Siwalik Chirpine Forest) and 3.76% of forest cover is under 9/C1b (Upper or Himalayan Chirpine Forest) (FSI 2019). Coniferous forests are important because they cover a large part of the earth's surface, representing the largest land habitat for plant and animal species. It occurs chiefly in Arunachal Pradesh, Himachal Pradesh, Uttarakhand and Punjab. In Himachal Pradesh, it is found in Kangra, Shimla, Solan, Sirmaur, Mandi, Chamba, Bilaspur, Kullu and Hamirpur (FSI 2019).

Forest fire and climate change reinforce each other and fires these days are more intense and last longer than they used to be earlier (Flannigan et al. 2000; Gavin et al. 2007). Wildfires are mainly due to human activities intentional or unintentional. The needle litter of chirpine is very combustible, making it prone to forest fires. The locals set fire to the pine forests every year to eliminate the needle litter, as the needles make it difficult for humans and animals to navigate through the forests. When there is a dearth of fodder, fire is set to encourage fresh grass growth before the monsoon rains. Accidents from road surfacing activity, cigarette butts thrown into the forest, and villagers traveling through the forest paths at night carrying lighted torchwood all contribute to forest fires and these fires then lead to a decrease in flora and fauna of forest ecosystem (Chandran et al. 2011).

Pine forests are most susceptible to frequent occurrence of fires every year. The pre to post fire consequences include decrease in frequency and density of understorey vegetation and most of the species decline immediately after fire particularly at higher altitudes (Kumar et al. 2013). There are instances of decrease in the number of seedlings and saplings in the areas with frequent instances of forest fires. Surface fires and ground fires affect the ground vegetation like grasses and also natural regeneration of various trees, herbs and shrubs (Joshi et al. 2013). The chances of soil erosion increase in burnt areas and it also alters the soil parameters and chemical properties. Forest fires affect the survival of plant growth promoting microbes and hence indirectly affects the plant growth (Mittal et al. 2019). So, keeping in view the precarious effects of wildfire on ecosystem as well as the local environment, this study aimed to assess the effect of forest fire on soil properties and natural regeneration of forest ecosystem. The findings will aid environmentalists and ecologists to work in other areas of the same region.

MATERIALS AND METHODS

Study area and period

The present investigation was carried out at six locations in Solan, Hamirpur and Kangra Districts of India (21°N 78°E / 21°N 78°E), Himachal Pradesh (Figure 1 and 2; Table 1): i.e., Solan Forest Division (Table 2), Hamirpur Forest Division (Table 3) and Dehra Forest Division (Table 4) in the year 2020. Studies were conducted in the natural fire affected area and nearby unburnt area at each site. The distance between burnt and unburnt areas was approximately 300m at each site. The administrative and geographical information of the study sites is detailed in Table 1. The geomorphological variables, accessibility, socio-economic condition and fire history of the study sites are presented in Tables 2, 3 and 4.

Data collection procedure

At each location, three soil samples from 0-15cm deep layers were drawn randomly from burnt areas and three from unburnt areas in the month of July during 2020 for soil analysis. Soil samples were air dried, grinded and passed through 2mm sieve and subjected to physico-chemical analysis.

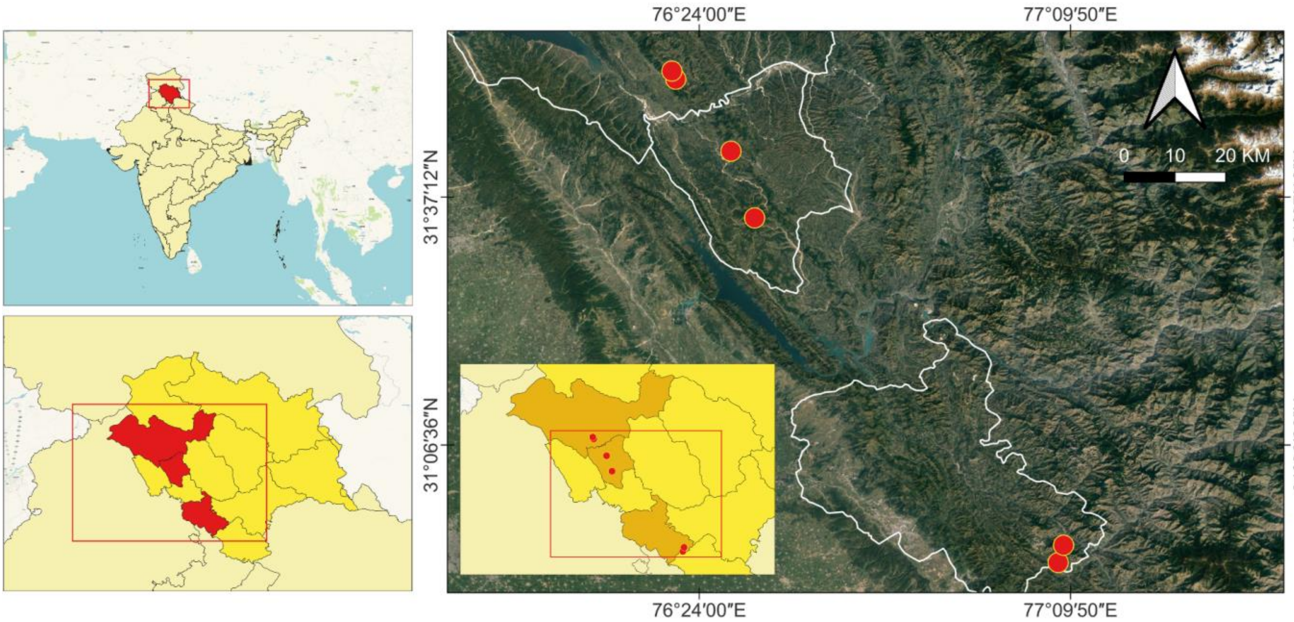

Figure 1. Map of study area in Himachal Pradesh, India

Table 1. Details of study sites in Himachal Pradesh, India

	Solan Forest Division		Hamirpur Forest Division		Dehra Forest Division	
	Oachhghat	**Jaunaji**	**Salauni**	**Jhaniari**	**Tehri 1**	**Tehri 1**
District	Solan	Solan	Hamirpur	Hamirpur	Kangra	Kangra
Range	Solan	Solan	Dehri	Hamirpur	Jwalamukhi	Jwalamukhi
Division	Solan	Solan	Hamirpur	Hamirpur	Dehra	Dehra
Altitude	1325 m	1379 m	1050 m	849 m	955 m	939 m
Latitude (^{0}N)	30.8682	30.9038	31.5773	31.7145	31.8627	31.8794
Longitude (^{0}E)	77.1384	77.1496	76.5138	76.4652	76.3516	76.3437

Regeneration potential of woody species through seeds in respect of density of seedlings of trees and shrubs and density of saplings of trees were observed in burnt and unburnt forests of all the selected sites. Natural regeneration potential was observed randomly in 20 quadrates of 5 x 5 m^2 for trees and shrubs under both the conditions, i.e., burnt and unburnt in all the selected sites. Regeneration potential of woody species through seeds in respect of density of seedlings of trees and shrubs and density of saplings of trees were observed in burnt and unburnt forests of all the selected sites (Kumar and Thakur 2008).

Data analysis

Soil physico-chemical analysis was done by using various methods (Table 5). Analysis of variance of the data collected was done through Completely Randomized Design (CRD factorial) as described by Panse and Sukatme (1967). Factors being analyzed were factor A (sites), factor B (conditions: burnt and unburnt) and interaction between sites and conditions. OP Stat was used for the analysis of data.

Table 2. Details of study areas of Solan Forest Division

Name	Oachhghat	Jaunaji
Geomorphology		
Slope	Moderate	Moderate
Rock type	Ferromagnesian, carbonaceous shales and dolomitic limestones	Ferromagnesian, carbonaceous shales and dolomitic limestones
Erosion	Moderate	Moderate
Soil structure	Sub-angular to blocky	Sub-angular to blocky
Approached by	Road	Road
Nearest town	Solan	Solan
Biotic interferences		
Dependence on forests for		
Fuelwood collection	Yes	Yes
Medicines	Yes	Yes
Grass cutting	Yes	Yes
Grazing	Yes	Yes
Other	Yes	Yes
Developmental activities	Construction	Construction
Fire history		
Causes	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers
Interval (in fire affected areas)	2015, 2017, 2018, 2019	2016, 2017, 2019

Table 3. Details of study areas of Hamirpur Forest Division

Name	Salauni	Jhaniari
Geomorphology		
Slope	Moderate	Moderate
Rock type	Ferromagnesian, carbonaceous shales and dolomitic limestones	Ferromagnesian, carbonaceous shales and dolomitic limestones
Erosion	Moderate	Moderate
Soil structure	Sub-angular to blocky	Sub-angular to blocky
Approached by	Road	Road
Nearest town	Hamirpur	Hamirpur
Biotic interferences		
Dependence on forests for		
Fuelwood collection	Yes	Yes
Medicines	Yes	Yes
Grass cutting	Yes	Yes
Grazing	Yes	Yes
Other	Yes	Yes
Developmental activities	-	-
Fire history		
Causes	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers
Interval (in fire affected areas)	2012, 2013, 2019	2013, 2019

Table 4. Details of study areas of Dehra Forest Division

Name	Tehri 1	Tehri 2
Geomorphology		
Slope	Moderate	Moderate
Rock type	Ferromagnesian, carbonaceous shales and dolomitic limestones	Ferromagnesian, carbonaceous shales and dolomitic limestones
Erosion	Moderate	Moderate
Soil structure	Sub-angular to blocky	Sub-angular to blocky
Approached by	Road	Road
Nearest town	Jwalamukhi	Jwalamukhi
Biotic interferences		
Dependence on forests for		
Fuelwood collection	Yes	Yes
Medicines	Yes	Yes
Grass cutting	Yes	Yes
Grazing	Yes	Yes
Other	Yes	Yes
Developmental activities	-	-
Fire history		
Causes	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers	Unextinguished bidis, cigarette butts, matchsticks etc., by forest laborers, graziers or by roadside charcoal panniers
Interval (in fire affected areas)	2014, 2015, 2019	2014,2015,2019

Table 5. Methods for physico-chemical properties of soil

Physico-chemical property	Method employed
Soil pH	1:2 Soil:Water suspension, measured with digital pH meter (Jackson 1973)
Electrical Conductivity (dS/m)	1:2 Soil:Water suspension, measured with digital EC meter (Jackson 1973)
Organic Carbon (kg/ha)	Walkley and Black wet digestion method (Walkley and Black 1934)
Available Nitrogen (kg/ha)	Alkaline $KMnO_4$ method (Subbiah and Asiza 1956)
Available Phosphorus (kg/ha)	Olsen method (Olsen et al. 1954)
Available Potassium (kg/ha)	Ammonium acetate method (Merwin and Peech 1951)

RESULTS AND DISCUSSION

In general, the result of our study indicated that physico-chemical properties of soil are altered due to fire and the changes may be conducive or detrimental to growth and development of plants.

Chemical properties of soil in burnt and unburnt areas

Table 6 depicts that the value of pH was higher in burnt forests (6.99) in all the sites compared to unburnt forests (6.49). This may be due to the increase of soluble cations in the ash. Similar result was reported by Rojas et al. (2016) and Tufekcioglu et al. (2010) in which soil pH is significantly higher in burned sites than in unburned sites. Soil pH usually changes due to fire and the extent of change depends upon the frequency and type of fire. Destruction of some organic acids and liberation of some bases may be the reason for this change.

The data is significant for electrical conductivity. The value of electrical conductivity in soil is higher in burnt forests (0.46 dS/m) as compared to unburnt forests (0.41 dS/m). The higher value of EC after fire is reported by Nigussie and Kissi (2011) and Rojas et al. (2016). There is also significant interaction between the factors of site and fire on electrical conductivity.

The data of organic carbon is statistically significant for burnt and unburnt conditions. Data regarding soil organic carbon (%) indicated that the value of organic carbon in soil decreased due to fire as it was found lower in burnt forests (0.60) as compared to unburnt forests (0.75) of all the sites. It may be because severe burns can result in complete destruction of organic matter and can even cause changes in physical, chemical and biological properties of the upper layer of soil. The results are almost similar to Kumar (2004) and Beyer et al. (2011). Decreased amount of soil organic matter after fire is also reported by Robyn et al. (2015) which persisted for about 25 months.

Soil nutrient status of burnt and unburnt areas

Table 7 shows that, the value of available nitrogen (kg/ha) was higher in burnt forests (394.01 kg/ha) as compared to unburnt forests (390.12 kg/ha) of all sites. The results are in line with Kumar (2004), Ekinci (2006) and da Silva and Batalha (2008). Nonetheless, the result for available nitrogen contradicted with the result of Robyn et al. (2015) who reported decreased amount of available nitrogen after fire and this decrease persisted for about 25 months.

Table 6. Chemical properties of soil in burnt and unburnt areas

Site	Soil pH			Organic carbon (%)			Electrical conductivity		
	B	UB	Mean	B	UB	Mean	B	UB	Mean
Solan Forest Division									
Oachhghat	6.43	5.68	6.06	0.84	0.98	0.91	0.4	0.32	0.36
Jaunaji	6.25	5.52	5.89	0.83	0.94	0.89	0.37	0.31	0.34
Hamirpur Forest Division									
Salauni	7.52	7.03	7.28	0.99	1	1	0.48	0.47	0.48
Jhaniari	7.94	7.6	7.77	0.66	0.71	0.68	0.57	0.5	0.54
Dehra Forest Division									
Tehri 1	6.66	6.46	6.56	0.12	0.43	0.28	0.45	0.42	0.44
Tehri 2	6.79	6.65	6.72	0.14	0.47	0.31	0.46	0.43	0.45
Mean value of burnt and unburnt conditions of all the selected sites									
Mean	6.99	6.49		0.60	0.75		0.46	0.41	
		pH			Organic carbon (%)			Electrical conductivity	
		CD (0.05)			CD (0.05)			CD (0.05)	
Site (S)		0.09			0.07			0.02	
Condition (C)		0.05			0.04			0.01	
Interaction SxC		0.12			0.10			0.03	

Note: B: Burnt, UB: Unburnt, CD: Critical difference

Table 7. Soil nutrient status of burnt and unburnt areas

	Available Nitrogen (kg/ha)			Available Phosphorous (kg/ha)			Available Potassium (kg/ha)		
	B	UB	Mean	B	UB	Mean	B	UB	Mean
Solan Forest Division									
Oachhghat	431.32	427.00	429.16	33.10	27.92	30.51	279.36	276.73	278.05
Jaunaji	400.73	392.53	396.63	31.87	27.77	29.82	240.63	237.86	239.25
Hamirpur Forest Division									
Salauni	380.20	374.93	377.57	31.27	29.82	30.55	251.20	248.33	249.77
Jhaniari	379.50	377.23	378.37	31.09	29.53	30.31	255.13	252.77	253.95
Dehra Forest Division									
Tehri 1	386.50	385.53	386.02	33.86	31.53	32.70	259.00	256.27	257.63
Tehri 2	385.80	383.46	384.63	32.97	31.17	32.07	260.43	258.13	259.28
Mean of burnt and unburnt conditions of all the selected sites									
Mean	394.01	390.12		32.36	29.62		257.63	255.02	
	Available Nitrogen (kg/ha)			Available Phosphorous (kg/ha)			Available Potassium (kg/ha)		
	CD (0.05)			CD (0.05)			CD (0.05)		
Site	2.15			1.05			1.43		
Condition	1.24			0.61			0.83		
Interaction SxC	3.04			1.48			NS		

Note: B: Burnt, UB: Unburnt, CD: Critical difference

The available phosphorus was higher in burnt sites that means it increased due to fire. This may be due to less organic matter in burnt areas. The mean value of available phosphorus in burnt areas was 32.36 kg/ha and in unburnt site was 29.62 kg/ha. The increases available phosphorus after fire has been reported by Kumar (2004) and Rojas et al. (2016). The value of available potassium (kg/ha) increased in burnt forest. This may be due to the addition of ash to the soil. The reason behind this may be the addition of plant ash due to fire that contains a large amount of potassium. Mittal et al. (2019) documented the increase of available potassium in burnt forests.

Regeneration potential of tree species in burnt and unburnt areas

Table 8 depicts that the density of seedlings was higher in burnt forests as compared to unburnt forests. Our finding is in accordance with the study by Konsam et al. (2017). Suitable conditions for regeneration and growth of seedlings of woody species in Chirpine forest is facilitated by fire and forest fire may also result in clearance of site which enhance natural regeneration.

In Solan Forest Division, the highest density of seedlings of *P. roxburghii* was observed in burnt forest of Oachhghat (1.15) followed by burnt) forest of Jaunaji (0.95, unburnt forest of Oachhghat (0.85), while the lowest was recorded in unburnt forest of Jaunaji (0.65). The highest density of seedlings of all the trees was observed in burnt forest of Oachhghat (1.65) and the lowest was in unburnt forest of Jaunaji (0.95).

In Hamirpur Forest Division, the highest density of seedlings of *P. roxburghii* was observed in burnt forest of Jhaniari (1.25) followed by unburnt forest of Jhaniari (1.15), burnt forest of Salauni (1.05) and the lowest was recorded in unburnt forest of Salauni (0.95). The highest density of seedlings of all the trees was in burnt forest of Jhaniari (2.95) and the lowest was in unburnt forest of Salauni (0.95).

In Dehra Forest Division, the highest density of seedlings of *P. roxburghii* was observed in burnt forest of Tehri 2 (1.45) followed by burnt and unburnt forests of Tehri 1 and Tehri 2 (1.35), while the lowest was recorded in unburnt forest of Tehri 1(1.30). The highest density of seedlings of all the trees was in burnt forest of Tehri 2 (1.7) and the lowest was in unburnt forest of Tehri 1 (1.35).

If compared across the sites, in unburnt conditions, the highest density of saplings of trees was recorded in Jhaniari with 3.30 followed by Oachhghat with 2.30, Tehri 1 with 1.60, Tehri 2 with 1.50, Salauni with 1.25 and the lowest density of saplings was 1.20 in Jaunaji and Jhaniari. The lower number of saplings in burnt forests were documented by Joshi et al. (2013).

Our findings suggest that the density of seedlings of trees was recorded to be higher in burnt conditions of all the studied sites whereas density of saplings of trees was recorded to be higher in unburnt conditions. These results are inline to the study by Kumar (2004). The higher density of seedlings in burnt conditions shows that natural regeneration is enhanced due to fire. On the other hand, Verma et al. (2017) reported decreased number of saplings after fire but increased after five years, indicating that frequent fires can be detrimental for saplings. Verma and Jayakumar (2015) suggested that one or two fires every 15 years can be beneficial to tree species regeneration. After one or two fires every 15 years with equal time intervals, plants have enough time and more available soil nutrients for regeneration.

Regeneration potential of shrubs in burnt and unburnt areas

Table 9 depicts that in Solan Forest Division the highest density of seedlings of shrubs within the sampling area of 25 m^2 was found in unburnt forest of Jaunaji (4.00), followed by burnt forest of Oachhghat (3.80), unburnt forest of Oachhghat (3.15) and the lowest was in burnt forest of Jaunaji (3.00).

In Hamirpur Forest Division, the highest density of seedlings of shrubs was found in burnt forest of Jhaniari (3.60) followed by burnt forest of Salauni (3.15), unburnt forest of Jhaniari (2.90) and the lowest was in unburnt forest of Salauni (2.50). In Dehra Forest Division, the highest density of shrubs was found in burnt forest of Tehri 1 (3.75) followed by burntforest of Tehri 2 (3.65) and the lowest was recorded in unburnt forests of Tehri 1 and Tehri 2 (1.95). Higher density of seedlings in burnt conditions shows that natural regeneration is enhanced due to fire. The higher density of seedlings in burnt forests as compared to unburnt forests is also reported by Kumar (2004); Konsam et al. (2017) and Verma et al. (2017).

Table 8. Regeneration potential of tree species (as total number of seedlings or saplings per 25 m^2) in burnt and unburnt areas

Name of tree species	Oachhghat		Jaunaji		Salauni		Jhaniari		Tehri 1		Tehri 2	
	B	UB	B	UB	B	UB	B	UB	B	UB	B	UB
Density of seedlings												
Pinus roxburghii	1.15	0.85	0.95	0.65	1.05	0.95	1.25	1.15	1.35	1.3	1.45	1.35
Quercus leucotrichophora	-	0.40	0.45	0.30	-	-	-	-	-	-	-	-
Pyrus pashia	0.50	0.30	-	-	-	-	-	-	-	-	-	-
Cassia fistula	-	-	-	-	-	-	0.20	0.10	-	-	-	-
Bombax ceiba	-	-	-	-	-	-	0.40	-	-	-	-	-
Shorea robusta	-	-	-	-	-	-	0.70	-	-	-	-	-
Acacia catechu	-	-	-	-	-	-	0.40	-	-	-	-	-
Ficus roxburghii	-	-	-	-	-	-	-	-	0.05	0.05	-	-
Toona ciliate	-	-	-	-	-	-	-	-	-	-	-	0.15
Grewia optiva	-	-	-	-	-	-	-	-	-	-	0.25	-
Total	1.65	1.55	1.40	0.95	1.05	0.95	2.95	1.25	1.40	1.35	1.70	1.50
Density of saplings												
Pinus roxburghii	0.95	1.05	0.65	0.75	1.00	1.25	1.20	1.00	0.90	1.35	1.20	1.30
Quercus leucotrichophora	-	0.50	0.40	0.45	-	-	-	-	-	-	-	-
Pyrus pashia	0.60	0.75	-	-	-	-	-	-	-	-	-	-
Cassia fistula	-	-	-	-	-	-	-	0.40	-	-	-	-
Bombax ceiba	-	-	-	-	-	-	-	0.50	-	-	-	-
Shorea robusta	-	-	-	-	-	-	-	0.80	-	-	-	-
Acacia catechu	-	-	-	-	-	-	-	0.60	-	-	-	-
Ficus roxburghii	-	-	-	-	-	-	-	-	0.20	0.25	-	-
Toona ciliata	-	-	-	-	-	-	-	-	-	-	-	0.20
Grewia optiva	-	-	-	-	-	-	-	-	-	-	0.30	-
Total	1.55	2.30	1.05	1.20	1.00	1.25	1.20	3.30	1.10	1.60	1.50	1.50

Note: B: Burnt, UB: Unburnt

Table 9. Regeneration potential of shrubs (as total number of seedlings per 25 m^2) in burnt and unburnt areas

Name of shrubs species	Oachhghat		Jaunaji		Salauni		Jhaniari		Tehri 1		Tehri 2	
	B	UB	B	UB	B	UB	B	UB	B	UB	B	UB
Berberis lyceum	0.75	0.60		-	-	-	-	-	-	-	-	-
Buddleia asiatica	-	-	0.50	-	-	-	-	-	-	-	-	-
Carissa carandus	0.65	0.75	0.50	-	0.80	0.50	0.95	0.80	0.70	0.65	0.95	0.65
Lantana camara	0.50	0.40	0.80	0.85	0.75	0.60	0.70	0.55	0.55	0.35	0.35	0.30
Murraya koenjii	0.95	-	-	-	1.05	0.95	0.65	0.50	0.85	0.45	0.85	0.55
Abrus precatorius	-	0.35	-	-	-	-	-	-	-	-	-	-
Rosa moschata	0.20	0.25	-	0.75	-	-	-	-	-	-	-	-
Rubus ellipticus	0.30	0.30	-	0.80	-	-	-	-	0.65	0.50	0.75	0.45
Urtica dioica	-	0.50	-	-	-	-	-	-	-	-	-	-
Woodfordia fruticosa	0.45	-	0.35	-	0.55	0.45	0.75	0.65	0.40	-	0.30	-
Spirea canescens	-	-	0.30	-	-	-	-	-	-	-	-	-
Myrsine Africana	-	-	0.55	0.65	-	-	0.55	0.40	-	-	-	-
Zanthoxylum alatum	-	-	-	0.35	-	-	-	-	-	-	-	-
Lespedeza gerardiana	-	-	-	0.60	-	-	-	-	-	-	-	-
Datura stramonium	-	-	-	-	-	-	-	-	0.60	-	0.45	-
Total	3.80	3.15	3.00	4.00	3.15	2.50	3.60	2.90	3.75	1.95	3.65	1.95

Note: B: Burnt, UB: Unburnt

In conclusion, our study shows that the physico-chemical properties of soil were altered due to fire. Electrical conductivity, pH, available nitrogen, available phosphorus, available potassium were higher in burnt forests when compared to unburnt forests of the studied sites whereas organic carbon (%) was lower in burnt forests as compared to unburnt forests. The density of seedlings of trees was higher in burnt forests as compared to unburnt forests whereas density of saplings of trees was recorded more in unburnt forests as compared to burnt forests. This indicates that fire is good for regeneration but frequent fires can be detrimental for the survival of those seedlings. Frequent forest fires need to be prevented and that can be done mainly by social awareness and developing strategies for use of pine needles in farming practices and commercial use in paper, pulp and wood industries.

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