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Response of understorey vegetation in chir pine forests to prescribed burning in Shiwalik region of Himalaya

R. Kumar

Himalayan Forest Research Institute, Shimla-171 013, India

***Corresponding Author Email :** ranjeet@icfre.org

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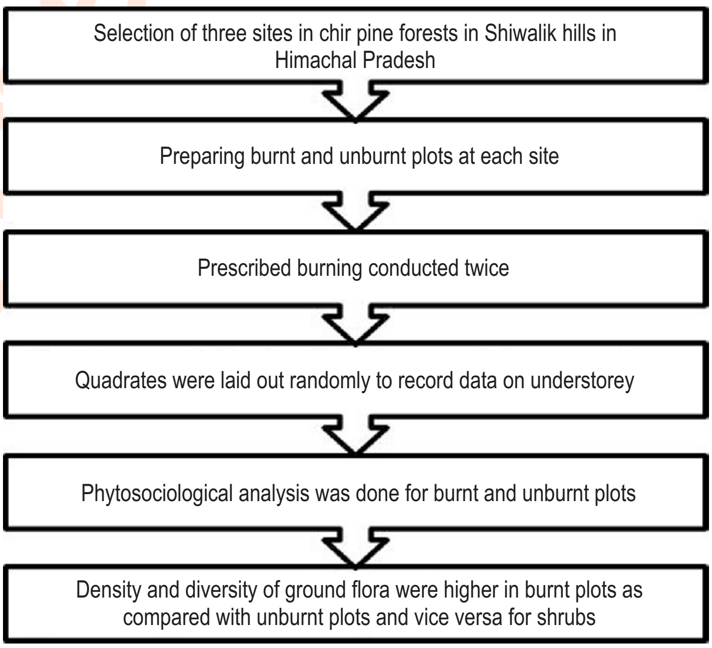
Abstract

Aim: The present investigation was carried out to understand the impact of controlled/prescribed burning on understorey vegetation in chir pine (*Pinus roxburghii*) forests of Shiwalik region to manage the summer fire damage.

Methodology: Chir pine forest areas of two hectares (ha) each were selected at three sites in Shiwalik region of Himalaya for prescribed burning. Each forest area was delineated into three plots of which one plot was burnt during mid-winter in the year 2017 (B_1) and another plot burnt twice (B_2) during 2017 and 2018 whereas the third was kept unburnt plot (C) in each site. The phytosociological attributes of understorey vegetation were studied in November, 2018. The difference in density of shrubs (plants 25 m^{-2}) and herbs (plants m^{-2}) in unburnt ©, once burnt (B_1) and twice burnt (B_2) was analyzed through critical difference (CD).

Results: Total density (plants 25m^{-2}) of shrubs ranged from 7.15 to 12.95 in unburnt (C), 3.90 to 8.40 in once burnt (B1) and 2.25 to 4.65 in twice burnt (B_2) plots whereas total density (plants m^{-2}) of herbs varied from 25.83 to 44.95 in unburnt (C), 33.20 to 75.92 in once burnt (B_1) and 29.31 to 90.93 in twice burnt (B_2) plots. The density of shrubs was significantly higher in unburnt plots (C) as compared to burnt plots and *vice versa* for herbs. The Shanonn Wiener Index (H) ranged from 1.76 to 2.39 for shrubs and 2.32 to 3.15 for herbs.

Interpretation: The density of herbs was higher in burnt plots and it was *vice versa* for shrubs. The prescribed burning enhanced diversity of herbs while shrubs diversity decreased with burning.



Key words: Chirpine forests, Density, Diversity, Prescribed burning, Shiwalik hills

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Introduction

India is one of the twelve mega diversity countries on the earth and lies between the junction of oriented bio-geographical provinces, temperate Eurasia and Africa (Chopra and Sharma, 2014). The northern part of India is home to the mountains of Himalaya (Owen, 2014). The main ranges of Himalayas are outer Himalaya, Lesser Himalaya and Greater Himalaya (Kumar *et al.,* 2020). The Himalaya has variation in the diversity of environment, landforms types and landscapes. The main reason for diversity is the strong east-west and north-south precipitation gradient (Owen, 2014). The Indian Himalayan region supports around 18,440 species of plants (Singh and Hajra, 1996; Pant and Samant, 2010). It is also one of the hot spot of biodiversity with 25-30 % of endemic plants (Singh and Hajra, 1996; Singh and Samant, 2010). Shivalik hills fall in outer Himalayan range. They are rich in plant diversity and known for their biogeography because of intermingling of taxa from palaearctic and Indo-Malayan regions (Puri *et al.,* 2018). The Shiwalik hills are the youngest mountain chain in India and range over Chandigarh, Uttrakhand, Haryana, Punjab, Himachal Pradesh and Jammu and Kashmir Union Territory (Puri *et al.,* 2018).

Forest fire is one of the common problems in various landscapes in the world. Forest fire disturbs the balance of earth ecosystem. It is very important to understand the impact of forest fire to know the plant and ecosystem evolution (Bond and Keeley, 2005; Pereira *et al.,* 2012) and causes ecological and economic problems. Forest fires are responsible for global warming and climate change (Silva *et al.*, 2010; Pereira *et al.,* 2012). Forest fire plays an important role in changing the composition of flora and forms an integral part of forest environment. The frequency of forest fire is dependent on fuel, oxygen and ignition. The dead and live biomass should be dry enough to burn. The flammability of live biomass depends on the moisture content of biomass (Bond and Keane, 2017). Chir pine (*Pinus roxburghii*), native to Himalaya, is dominant tree species in the forests of Shivalik hills. Forest fire is one of the major problem in subtropical pine forests that cover 18102 km^2 area which is 2.3 % of total area of different forest types of India (FSI, 2019) and are located between 450 m to 2300 m altitude (Kumar *et al.,* 2007). They are generally found as pure forests in their main habitat but in lower and upper altitudinal range they are mixed with other broad leaves and conifer species.

Shiwalik forests often experience fires during summer because these trees shed their leaves which contain resin and are susceptible to fire. Forest fires occur almost every year in these forests. The main reasons of forest fire are intentional or un-intentional, but ignition is most often set to disrupt the forest operations or increasing the density of ground flora (Kumar *et al.,* 2013). Forest fire mainly affects the underground shrubs, saplings, herbs, natural regeneration of trees and shrubs. The effect of forest fire mainly depends upon frequency and type of fire. Chir pine forests of shiwalik hills are adversely affected by severe intensity of fire so there is a need for managing forest resources by using tools like prescribed burning/controlled burning to improve the health of the ecosystems of chir pine landscapes. The use of prescribed or controlled burning can improve ecosystem structure and species composition (Bond and Keane, 2017), hence, assessment of vegetation after prescribed burning is important. The prescribed burning can also be used as tool with the objective to enhance the diversity of chir pine forests. The present study was conducted with aim to understand the impact of prescribed burning on density of understorey vegetation chiefly shrubs, herbs, saplings and natural regeneration of trees and shrubs.

Materials and Methods

The reconnaissance survey was conducted in the zone less then 900 m above mean sea level in subtropical pine forests in Nahan, Renuka and Paonta Sahib Forest Divisions where the occurrence of forest fire is common. Three localities *i.e.,* Dhon, Smonkanon and Sarlimanpur in Shiwaliks were randomly selected for investigations. An area of 2 ha was marked in each site for assessing vegetation properties.

Prescribed burning: Out of two hectare area in each site, 1.50 ha was burnt in the year 2017 in winter season, and the remaining 0.50 ha was kept as unburnt (C). In the year 2018, 1.00 ha (B_2) area was burnt again in winter and 0.50 ha (B_1) was not burnt in this year. During prescribed burning, understorey vegetation was burnt by setting low intensity fires. The vegetation change was thus studied on once burnt (B_1), twice burnt (B_2) and unburnt plots (C).

Data collection: The data was recorded for shrubs, sapling, herbs and natural regeneration of trees and shrubs from burnt and unburnt plots by laying out randomly 20 quadrates measuring 5m x 5m for woody vegetation (shrubs and saplings) and 40 quadrates measuring 1m x 1m for the ground flora (herbs, natural regeneration of trees and new shoots of shrubs) in C, B_1 and B_2 plots during November 2018. Individuals having circumference breast height (CBH) between 10.40 cm to 31.50 cm were considered as saplings and <10.40 cm were taken as seedlings or natural regeneration (Knight, 1963; Pala *et al.* 2022). The data for phytosociology of individuals shrubs and herbs *viz.,* number and diameter were recorded.

Phytosociological analysis: The density (D), frequency (F), abundance (A) and Importance value index (IVI) of individual species was calculated by following the method given by Curtis and Mcintoch (1950). The sum total of relative value of density, basal area and frequency (%) of an individual plant species provided its Importance Value index (IVI). The Shanonn-Wiener diversity index (H) was calculated as per the method of Shanonn-Wiener (1963). Concentration of dominance (Cd) was determined by Simpson Index (Simpson, 1949).

Statistical analysis: Randomized block design was used to observe the impact of prescribed burning on shrubs and herbs. The average number of individuals of two quadrates of shrubs was taken as one replication whereas for herbs the average of number of individuals of four quadrates was taken as one replication. The unburnt C, once burnt (B_1) and twice burnt (B_2) were three treatments. The critical difference was calculated at 5% level of significance. The critical difference test was used for comparing the number of individuals of shrubs and herbs between unburnt (C), once burnt (B_1) and twice burnt (B_2) plots.

Results and Discussion

Anthropogenic intentional surface fires of low to high intensities are common phenomenon in chir pine forests in Shiwaliks. The prescribed burning can be used as a management tool to improve and maintain floral diversity in chir pine forests, however, there is no reliable information available which can authenticate it. So, the present study was conducted at three sites to determine impact of prescribed burning on understorey plant diversity. Total number of 48 species belonging to 46 genera and 28 families was recorded in all study sites. Comparing the unburnt, once burnt and twice burnt plots *viz.,* C, B_1 and B_2, not much difference in total number of species was recorded with 42, 44 and 44 species, respectively. While differentiating unburnt, once burnt and twice burnt plots at three sites *viz.,* Dhon, SamonKanon and Sarlimanpur, the total number of understorey species (shrubs, herbs, regenerating trees and shrubs seedlings) ranged from 18 (Dhon C) to 34 (Sarlimanpur B_2). The number of species of shrub was higher (17) in C as compared to burnt treatments (B_1=16 and B_2=14). The number of herbs were higher in burnt plots (B_1=36 and B_2=38) as compared to C (33).

The number of woody species (shrubs and saplings of trees) ranged from 6 (Dhon B_1 and B_2) to 12 (Sarlimanpur C) (Table 1). The number of species of herbs, natural regeneration of shrubs and trees ranged from 17 (Dhon C) to 25 (Sarlimanpur B_1) (Table 1). Forest fires are natural or anthropogenic disturbances that occurs across the world affecting the vegetation by suppressing certain species and encouraging other species causing changes in vegetation structure and successional pattern (Brown, 1960; Reich *et al.,* 1990) resulting in change in diversity of shrubs and herbs. In this study, it was evident that floral changes in vegetation were not phenomenal, perhaps due to short tenure of the study. Long duration studies are required to reach at a conclusion regarding floral changes. The density (plants 25 m^{-2}) of shrubs and tree saplings in different plots at three sites did not show specific trend in unburnt (C) and burnt (B_1 and B_2) plots (Table 2) but, in general, total density (plants 25 m^{-2}) decreased after burning in all plots. It was evident that at Dhon significant difference (F calculated = 64.487, F tabulated = 3.554, CD= 0.92 and p value <0.05) occurred in total number of individuals of all shrubs (plants 25 m^{-2}) between C (7.15), B_1 (3.90) and B_2 (2.25). The density of shrubs at SamonKanon showed that C (12.15) was significantly higher (F calculated = 8.585, F tabulated = 3.554, CD= 4.15 and p value <0.05) from B_1 (5.65) and B_2 (4.60). However, shrubs density at B_1 (5.65) and B_2 (4.60) at Samon Kanon was statistically at par. Similarly, the shrub density in C (12.95) at Sarlimanpur was significantly higher (F calculated = 27.977, F tabulated = 3.554, CD= 2.33 and p value <0.05) from B_1 (8.40) and B_2 (4.65) and density of shrubs in B_1 (5.65) and B_2 (4.60) was statistically at par at this site (Table 2). The woody species like *Mallotus philippensis*, *Murraya koenigii* and *Pinus roxburghii* were found in all plots (Table 2).

The saplings of *Flacourtia indica* and *Sapium insigne* were found only in unburnt plots (C) and *Myrsine africana* was only found at once burnt plots (B_1) (Table 2). Thus, the total density (plants 25 m^{-2}) of shrubs decreased after prescribed burning as evident from the results all three locations. Total density (plants 25 m^{-2}) of saplings of trees was highest (4.15) in unburnt plots at Dhon, followed by 3.80 in unburnt plot at Samon Kanon and lowest (1.15) at twice burnt plot at Samon Kanon (Table 1). The results revealed that tree sapling density was affected by burning. Similar results were reported by Kerry *et al.* (2006) after burning. Higher number of individuals of woody vegetation in plots 'C' at each location compared to burnt plots is similar to the findings of Allain and Grace (2001). The change in density of woody species after burning can be attributed to time of burning of vegetation, *i.e.,* dormant season at the time of fruit or seed formation or senescence when carbohydrate reserves are minimum in plants (DiTomaso *et al.,* 2006). Further, grazing disturbance following burning may aggravate the problem which accounts for decreased resprouting of woody plants in burnt plots. Analyzing the data for herbs including seedlings/natural regeneration of trees and shrubs revealed that the total density (plants m^{-2}) of

Table 1: Species number and density of natural regeneration (saplings and natural regeneration of trees and shrubs) in unburnt (C), once burnt (B_1) and twice burnt (B_2) in chir pine forests in Shiwalik Hills

Number of species and density	Dhon			SamonKanon			Sarlimanpur		
	C	B_1	B_2	C	B_1	B_2	C	B_1	B_2
Number of species of shrubs and saplings of trees	08	06	06	10	09	09	12	10	09
Number of species of herbs, natural regeneration of shrubs and trees	17	23	23	18	21	21	24	25	27
Density (plants 25m^{-2}) of saplings of trees	4.15	1.45	1.30	3.80	1.70	1.15	2.70	2.45	1.50
Density (plants 25m^{-2}) of natural regeneration of trees and shrubs	2.14	3.77	4.49	2.67	4.41	5.06	0.68	1.26	1.88

Table 2: Density (plants 25m^{-2}) and Importance value Index (IVI) of shrubs at selected unburnt ©, once burnt (B_1) and twice burnt (B_2) plots in chir pine forests in Shiwalik hills

Name of species	Dhon			SamonKanon			Sarlimanpur			Average density (plants 25m^{-2})
	C	B_1	B_2	C	B_1	B_2	C	B_1	B_2	
Buddleja asiatica							0.60 (16.12)	1.25 (32.01)	0.75 (38.66)	0.87
Carissa carandas	1.50 (56.54)	1.00 (53.94)	0.75 (72.91)	1.75 (38.92)	0.95 (34.36)	0.65 (36.92)	1.25 (26.16)		0.65 (36.82)	1.06
*Cassia fistula**	0.75 (35.2)	0.40 (42.15)	0.20 (36.16)	0.55 (26.96)	0.40 (28.07)	0.20 (24.37)				0.42
Colebrookea oppositifolia							0.85 (20.6)	0.70 (27.64)	0.40 (30.83)	0.65
*Dalbergia sissoo**							0.85 (18.69)	0.95 (30.46)	0.40 (29.85)	0.73
*Flacourtia indica**	1.00 (41.65)									1.00
Lantana camara				1.45 (22.02)	0.70 (35.66)	0.60 (34.09)	0.95 (22.55)			0.93
Maesa indica				1.90 (37.75)	1.10 (46.74)	0.75 (42.94)				1.25
*Mallotus philippensis**	0.55 (29.22)	0.35 (39.23)	0.25 (41.92)	0.95 (20.8)	0.45 (31.48)	0.25 (25.35)	0.65 (24.45)	0.70 (24.98)	0.15 (25.55)	0.48
Murraya koenigii	1.50 (51.26)	1.45 (74.44)	0.20 (36.7)	1.80 (37.66)	0.60 (29.22)	0.80 (41.16)	2.60 (50.98)	1.90 (53.52)	0.75 (40.71)	1.29
Myrsine africana								0.70 (32.69)		0.70
*Pinus roxburghii**	0.40 (19.82)	0.30 (36.17)	0.45 (60.97)	0.70 (21.37)	0.35 (24.37)	0.35 (30.02)	0.55 (18.09)	0.45 (24.59)	0.35 (28.4)	0.43
*Pyrus pashia**	0.90 (34.1)			1.00 (31.04)	0.50 (30.75)	0.35 (30.3)	0.65 (16.07)	0.35 (21.56)	0.60 (34.06)	0.62
Rhus parviflora							2.70 (49.1)	0.65 (29.97)	0.60 (35.13)	1.32
Rubus ellipticus				1.45 (39.41)	0.60 (39.34)	0.65 (34.87)	0.55 (19.01)			0.81
*Sapium insigne**				0.60 (24.07)						0.60
*Shorea robusta**	0.55 (32.21)	0.40 (54.07)	0.40 (51.34)							0.45
Zanthoxylum armatum							0.75 (18.19)	0.75 (22.58)		0.75
TOTAL	**7.15**	**3.90**	**2.25**	**12.15**	**5.65**	**4.60**	**12.95**	**8.40**	**4.65**	**6.86**
F Calculated		64.487			8.585			27.977		
F Tabulated		3.554			3.554			3.554		
CD		0.92			4.15			2.33		
p value		<0.05			<0.05			<0.05		

Value of Importance Value Index (IVI) are in parenthesis and *Saplings of trees

Ageratum conyzoides, *Ageratina adenophora* and *Heteropogon contortus* in burnt and unburnt plots was highest at Dhon, SamonKanon and Sarlimanpur, respectively (Table 3).

At Dhon, the herb density (plants m^{-2}) of C (31.84) was significantly lower (F calculated = 41,577, F tabulated = 3.554, CD= 8.40 and p value <0.05) from B_1 (59.43) and B_2 (66.30) whereas B_1 (59.43) and B_2 (66.30) was statistically at par in this site. The herb density (plants m^{-2}) at SamonKanon showed that C (44.95) was significantly lower (F calculated = 11.728, F tabulated = 3.554, CD= 20.35 and p value <0.05) from B_1 (75.92) and B_2 (90.93) whereas B_1 (75.92) and B_2 (90.93) were not significantly different with each other at SamonKanon. Similarly, the herb density (plants m^{-2}) of C (25.83) at Sarlimanpur was significantly lower (F calculated = 39.569, F tabulated = 3.554, CD= 2.70 and p value <0.05) from B_1 (33.20)

Table 3: Density (plants m^{-2}) and Importance Value Index (IVI) of herbs at selected unburnt ©, once burnt (B_1) and twice burnt (B_2) plots in chir pine forests in Shiwalik Hills

Name of species	Dhon			SamonKanon			Sarlimanpur			Average density (plants m^{-2})
	C	B_1	B_2	C	B_1	B_2	C	B_1	B_2	
Achyranthes aspera							0.05 (6.76)	0.15 (7.05)	0.35 (9.56)	0.18
Adiantum lunulatum	0.45 (7.37)	0.55 (12.97)	0.73 (9.41)	1.03 (8.68)	1.58 (12.85)	1.80 (14.15)	1.75 (11.13)	3.15 (26.67)	1.05 (11.12)	1.34
Ageratina adenophora	0.90 (10.75)	0.90 (6.31)	0.65 (6.95)	24.10 (85.13)	41.45 (82.07)	48.95 (82.87)	0.43 (7.82)	1.53 (12.28)	0.78 (6.9)	13.30
Ageratum conyzoides	22.23 (112.37)	38.10 (92.57)	44.88 (94.97)	2.28 (20.48)	2.53 (11.99)	2.53 (10.21)	0.38 (6.72)	0.85 (10.41)	0.75 (9.32)	12.73
Ajuga bracteosa				0.23 (14.11)						0.23
Bidens pilosa					0.80 (10.97)	1.70 (13.62)				1.25
*Carissa carandas***	0.23 (16.04)	0.50 (8.39)	0.63 (12.10)	0.20 (10.07)	0.75 (7.84)	1.13 (8.18)				0.57
*Cassia fistula**	0.25 (3.94)	0.50 (5.01)	0.83 (4.76)	0.30 (9.71)	0.58 (8.71)	0.75 (8.49)				0.54
Cheilanthes farinosa		0.55 (14.97)	0.30 (7.74)	0.38 (9.70)	0.70 (5.39)	1.70 (12.09)	0.68 (9.76)	1.53 (14.21)	0.78 (7.06)	0.83
Chrysopogon gryllus							2.50 (26.5)	4.13 (18.13)	4.95 (24.76)	3.86
Chrysopogon montanus	2.30 (20.44)	5.88 (25.84)	5.33 (24.21)	2.55 (17.1)	4.23 (17.27)	5.15 (16.41)	3.70 (36.16)	3.23 (15.75)	1.55 (12.83)	3.77
Cissampelos pareira	0.28 (6.87)	0.63 (7.24)	0.40 (8.92)				0.05 (6.48)	0.15 (5.44)	0.08 (6.97)	0.27
Cynodon dactylon					2.78 (18.77)	2.78 (17.59)				2.78
Cynoglossum foliosum							0.15 (5.99)	0.10 (6.25)	0.20 (4.98)	0.15
Dicliptera bupleuroides	0.23 (6.57)	0.40 (5.36)	0.50 (5.38)	0.65 (8.33)	0.78 (6.32)	0.78 (5.86)	0.23 (7.36)	0.70 (9.79)	0.78 (9.81)	0.56
Erigeron vulgare							0.05 (6.60)	0.23 (6.94)	0.20 (5.69)	0.16
Eulaliopsis binata				2.28 (20.48)	5.90 (19.76)	2.65 (11.30)	0.28 (7.92)	1.13 (13.67)	0.95 (6.51)	2.20
Euphorbia hirta							0.23 (8.07)	0.63 (9.56)	0.90 (8.97)	0.59
Euphorbia sp.					0.70 (5.39)	0.70 (5.01)				0.70
*Flacourtia indica**		0.53 (7.88)	0.55 (9.63)				0.25 (6.93)	0.48 (9.28)	0.63 (10.91)	0.49
Fragaria vesca	0.13 (10.18)	0.63 (7.24)	0.50 (6.01)	0.55 (4.95)	0.63 (5.66)	0.63 (5.29)	0.98 (11.10)	0.93 (10.68)	0.85 (9.41)	0.65
Galium aparine		0.30 (4.63)	0.58 (6.60)					0.35 (7.99)	0.35 (8.80)	0.40
Geranium wallichianum							0.10 (6.87)	0.15 (6.10)	0.20 (11.33)	0.15
Girardinia heterophylla							0.05 (3.95)	0.20 (5.14)	0.28 (10.52)	0.18
Heteropogon contortus	2.30 (19.47)	5.38 (27.66)	4.80 (20.38)	2.55 (14.65)	5.15 (23.41)	7.75 (20.40)	11.63 (73.23)	9.13 (46.73)	7.23 (43.29)	6.21
Hydrocotyle asiatica	0.40 (14.86)	0.58 (8.64)	0.58 (6.60)							0.52

Table continued

Name of species	Dhon			SamonKanon			Sarlimanpur			Average density (plants m^{-2})
	C	B_1	B_2	C	B_1	B_2	C	B_1	B_2	
*Lantana camara***				1.13 (7.20)	0.50 (9.21)	0.50 (8.82)				0.71
Leucas lanata		0.45 (7.15)	0.65 (6.15)				0.10 (7.53)	0.23 (4.01)	0.40 (11.25)	0.37
*Mallotus philippensis**	0.33 (6.46)	0.33 (6.94)	0.50 (5.35)	0.28 (8.97)	0.63 (14.20)	0.65 (13.70)				0.45
Malvastrum tricuspidatum							0.18 (6.32)	0.28 (7.01)	0.35 (8.76)	0.27
*Murraya koenigii***	0.38 (23.93)	0.58 (8.64)	0.45 (8.45)	0.53 (15.89)	0.65 (5.23)	0.75 (4.95)				0.56
Oxalis corniculata	0.48 (16.06)	0.48 (6.42)	0.65 (9.35)	2.55 (14.65)	1.73 (6.58)	3.50 (8.90)	1.25 (12.31)	2.53 (17.64)	2.05 (14.57)	1.69
Panicum maximum									1.55 (12.83)	1.55
*Pinus roxburghii**	0.25 (11.32)	0.45 (8.61)	0.50 (11.92)	0.23 (6.80)	0.65 (7.21)	0.63 (6.78)	0.20 (5.94)	0.40 (10.24)	0.65 (9.84)	0.44
*Pyrus pashia**	0.30 (6.55)	0.45 (7.52)	0.55 (5.34)		0.65 (9.59)	0.65 (9.14)	0.23 (7.96)	0.38 (8.77)	0.60 (5.70)	0.48
*Shorea robusta**	0.40 (6.82)	0.43 (7.11)	0.48 (11.07)							0.44
Solanum xanthocarpum									0.15 (8.40)	0.15
Sonchus asper		0.45 (4.95)	0.63 (9.36)							0.54
Themeda anathera				3.13 (23.11)	2.55 (11.59)	5.25 (16.23)				3.64
Viola serpens		0.38 (7.97)	0.63 (9.36)				0.38 (10.59)	0.63 (10.26)	0.70 (9.92)	0.54
TOTAL	**31.84**	**59.43**	**66.30**	**44.95**	**75.92**	**90.93**	**25.83**	**33.20**	**29.31**	**50.86**
F Calculated		41.577			11.728				39.569	
F Tabulated		3.554			3.554				3.554	
CD		8.40			20.35				2.70	
p value		<0.05			<0.05				<0.05	

Value of Importance Value Index (IVI) are in parenthesis and *is natural regeneration of trees and shrubs

and B_2 (29.31) whereas B_1 (33.20) and B_2 (29.31) at Sarlimanpur was statistically at par (Table 3). The total density (plants m^{-2}) of herbs, natural regeneration of trees and shrubs increased after prescribed burning at three sites. *Ajuga bracteosa* was found only in unburnt plot and the species is found in moist site. *Bidens pilosa*, *Cynodon dactylon*, *Euphorbia* sp., *Galium aparine* and *Sonchus asper* were found only in burnt plots (B_1 and B_2). *Panicum maximum* and *Solanum xanthocarpum* were recorded in twice burnt plot (B_2) (Table 3).

Some of the herbs were present in all the treatments, but clear cut trend was not observed and response for number of individuals was site specific (Savadogo *et al.,* 2008). Increased number of herbs after prescribed burning, perhaps due to lesser competition for space light and nutrients that increase the chances of establishment of native species has been reported by DiTomaso *et al.* (1999) and Kumar (2021) and creating favorable germination microsites (Valko *et al.,* 2014) and burning interrupts the successional replacement of ground flora by woody species (Axelrod, 1985). However, the impact of burning also depends upon season of burning and quantity of fuel load present on the ground floor in chir pine forest. Sometimes the prescribed burning also burn the seeds in litter layer. The total density of natural regeneration of trees and shrubs for all species was maximum (4.49) in twice burnt plot at Dhon, followed by 4.41 in twice burnt plot at SamonKanon and minimum (0.68) in unburnt plot at Sarlimanpur (Table 1). The number of individuals per meter square of new shoots of woody species were higher in burnt plots. The positive impact of prescribed burning on natural regeneration of woody species has also been supported (Meyer

Table 4: Concentration of dominance (Cd) and diversity index (H) of shrubs and herbs in unburnt (C), once burnt (B_1) and twice burnt (B_2) in chir pine forests in Shiwalik hills

Sites	C		B_1		B_2	
	Cd	H	Cd	H	Cd	H
Dhon	0.136 (0.171)	2.04 (2.32)	0.178 (0.126)	1.76 (2.65)	0.179 (0.127)	1.76 (2.67)
Samonkanon	0.106 (0.116)	2.27 (2.56)	0.115 (0.107)	2.18 (2.68)	0.115 (0.107)	2.18 (2.70)
Sarlimanpur	0.101 (0.097)	2.39 (2.79)	0.108 (0.061)	2.27 (3.03)	0.113 (0.053)	2.19 (3.15)

Values of herbs are in parenthesis

and Schiffman, 1999; Phillips and Waldrop, 2008). The impact of prescribed burning on structure of individual species in plant communities was studied by comparing IVI (Table 2, 3).

The clear cut trend of impact of burning on dominance of shrubs was not found on the basis of IVI (Table 2). *Ageratum conyzoides*, *Ageratina adenophora* and *Heteropogon contortus* were dominant species at Dhon, SamonKanon and Sarlimanpur, respectively, in all the treatments and displayed better establishment after fire with high IVI values in all the treatments (C, B_1 and B_2) (Table 3). Prescribed burning can be used for controlling invasive alien plant species by killing above ground tissues before flowering and seed setting. The burning had decreased the relative proportion of dominance (IVI) of invasive alien plant species (*Ageratum conyzoides* and *Ageratina adenophora*) in burnt sites at Dhon and SamonKanon which is associated with regeneration of native species (Keeley, 2003). The maximum value of Concentration of dominance (Cd) for shrubs was 0.179 at Dhon (B_2) and minimum (0.101) at Sarlimanpur (C) (Table 4). The maximum value of Cd for herbs 0.171 at Dhon (C) and minimum (0.053) at Sarlimanpur (B_2) (Table 4). The value of Concentration of dominance (Cd) in burnt sites was higher for shrubs and vice versa for herbs.

The concentration of dominance was inversely proportional to diversity index (H). The system has dominance of individuals of one or few species only means that the diversity is less than the system and has dominance of equal or near equal (Thukral *et al.,* 2019). The dominance of few species indicate that these species have better adaptation after burning or in the present environment. The higher value of Concentration of dominance revealed the homogeneous nature of dominant plant communities of herbs in unburnt plots whereas for shrubs in burnt plots (Kohli, 2004). The maximum value of Shannon-Wiener index (H) for shrub was 2.39 at Sarlimanpur (C) and minimum (1.76) at Dhon (B_1 and B_2) (Table 4). The diversity (H) of shrubs was higher in unburnt plots (C) at each site whereas the diversity of shrubs decreased after prescribed burning in burnt plots (B_1 and B_2). The historical disturbances regime in any ecosystem like periodic fires, anthropogenic pressures and species adaptation are also responsible for maintaining the diversity in any site in addition to prescribed burning. The decrease in shrubs richness has also been reported after burning by Kerry *et al.* (2006). The highest value (3.15) of H for herbs was Sarlimanpur (B_2), while the lowest (2.32) was at Dhon (C) (Table 4). The prescribed burning enhances the diversity of herbs. The heterogeneity is created after burning (Collins and Stephens, 2010) and responsible for enhancement of diversity (Huston, 1994). Germination of native herb species is encouraged due to consumption of unconsolidated litter lying on the ground by burning as stated by Bates and Svejcar (2009). The easy availability of propagating material of native species also enhance the diversity. The establishment of invasive alien plant species are also deterred or hindered by relative higher proportion of dominance by native species and the richness of native species is considered a good predictor for establishment of invasive alien plant species (Brown and Peet, 2003; Hunter *et al.,* 2006). Prescribed burning also increased the nutrient return from residue left after burning on the soil surface which may also be one of the factors of promoting plant growth of different species of herbs in burnt plots (Gautam and Mandal, 2016; Chen *et al.,* 2019) and enhancing the diversity. On the basis of higher IVI, *Ageratum conyzoides* community and *Ageratina adenophora* community were found at Dhon and Samon Kanon, respectively. The higher diversity in burnt plots in these two invasive alien plant dominant communities was recorded which was also reported by researchers (Floyd *et al.,* 2006; Valko *et al.,* 2014; Kumar, 2021).

Thus, it can be inferred from the study that prescribed burning increases the density and diversity of ground flora including natural regeneration of trees and shrubs and vice-versa for woody under storey vegetation. The prescribed burning can be practiced for forest fire management to manage the impact of forest fire on plant diversity and natural regeneration. Therefore prescribed burning can be a good ecological tool for management of chirpine forests.

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