Biological Forum – An International Journal **13(1): 312-323(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Studying the Effect of Controlled Burning on Invasive Plant Dominant Communities in Lower Altitude Chirpine Forests in Sirmaur District, Himachal Pradesh

Ranjeet Kumar
Himalayan Forest Research Institute (HFRI), Panthaghati, Shimla, India.

(Corresponding author: Ranjeet Kumar)
(Received 27 February 2021, Accepted 30 March, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The invasive alien plant species are changing composition and structure of vegetation leading to homogenization of flora. The biodiversity in chirpine forest in Himachal Pradesh is under threat due to increasing population of invasive alien plant species. The present papers deals with studying the impact of controlled burning on ground flora in chirpine forest. A study was conducted at three sites i.e. Dhon in Nahan Forest Division, Samon Kanon in Paonta Forest Division and Sarlimanpur in Renuka Ji Forest Division. The study site Dhon was dominated by *Ageratum conyzoides* and Samon Kanon by *Agerentina adenophora*. The study site Sarlimanpur was not dominated by these invasive alien plant species. The controlled burning was conducted in last week of February, 2017 in 1.50 hectare (B) in three sites with 0.50 hectare area kept control (C). The observation on phytosociological aspects for ground flora was taken in November, 2017. Total numbers of 34 species was recorded in control (C) and 37 in burnt (B). The diversity index ranges from 2.33 to 3.03. The diversity was higher at burnt as site as compare to control site in invasive as well as non-invasive plant dominant communities.

Keywords: Chirpine forests, Controlled burning, Invasive Alien species, Phytosociology

I. INTRODUCTION

Forest fire is one of the cause of degradation, pollution and invasion of exotic plants in various ecosystems of the world. The exotics plants found in forests are also known as invasive alien plant species. There are many evidences of establishment of non native species after intense wild fires (Hunter *et al*., 2006; Crawford *et al*., 2001; Griffis *et al*., 2001and Keeley *et al*., 2003). The invasive alien plant species spread outside of their natural distribution (Sekar, 2015). Invasive alien plant species cause the second highest damage to plant diversity than habitat losses (Hobbs and Humphries, 1995). Invasive alien plant species can cause ecological and economical losses due to introduction of these species in various parts of the world (Chaudhary, *et al*., 2019 and Anderson, 2005). These species effect the indigenous plant due to high competition for soil nutrient, space, light directly and effect also indirectly ecosystem services (Kaur *et al*., 2012; Goodell, 2008 and Weidenhamer & Callaway, 2010). The invasive alien species changes composition and structure significantly (Kaur *et al*., 2012; Cushman & Gaffney, 2010). *Ageratum conyzoides* and *Ageratina adenophora* are the main invasive species found in the ground floor of chirpine forests in foothills of Northern Western Himalayas.

Ageratum conyzoides commonly known as phulunu belong to family Asteraceae and is distributed in sub-tropical and tropical countries (Kaur *et al.,* 2012; Batish, 2008; Batish *et al*., 2009a and b). It has 30 species under the genus Ageratum and having origin in America (Kaur *et al*., 2012 and Okunade, 2002).

Ageratina adenophora commonly known as crofton weed or kala ghass is one of invasive alien plant species and belong to family Asteraceae. The species is spreading in North Western Himalayan region in India. The *Ageratina adenophora* is native to tropical America (Bhardwaj *et al.,* 2014).

Both of the above species are major threat to the native ground flora and also affecting adversely the establishment of natural regeneration of woody vegetation in chirpine forests.

Human beings have practiced the fire management tool since prehistoric times to encourage the establishment of useful plant species and also affecting the fire regimes in fire prone areas (DiTomaso *et al*., 2006 and Vale, 2002). Chir pine forests are adapted to some extent of forest fire disturbances.

The controlled burning is one of viable option to mitigate the negative impact of forest fires in chirpine forests and promoting biodiversity. The season of controlled burning, forest floor biomass fuel conditions, weather conditions, aspects, topography are the factors responsible for species composition and diversity in chirpine forests. The knowledge on the plant community is essential to know the impact of burning and the factors which favour the invasive species (Rice & Smith, 2008). Although various authors have worked on impact of burning on invasive species (Garcia, 2015; Pyke *et al.*, 2013; Flory *et al.*, 2012; Van Wilgen, 2009; Rice and Smith, 2008; Zouhar *et al.*, 2008; Hunter *et al.*, 2006; Floyd *et al*., 2006; DiTomaso *et al.*, 2006; Keeley, 2000; Pollak and Kan, 1998, Karl *et al*., 2018 and Andreasen *et al*., 2020 and Kumar *et al*., 2020) but the literature on site specific impact of control burning on invasive alien species is scanty (Rice & Smith, 2008) and especially on effect of controlled burning in chirpine forests. The controlled burning can be used to decrease the population of invasive species by direct mortality and depleting carbohydrate reserves (Rice & Smith, 2008). So the present investigation was carried out with objective to assess the impact of controlled burning on phytosociology of herbs including natural regeneration of trees and shrubs in invasive alien plant dominant communities in chir pine forests.

II. MATERIAL AND METHODS

A. Study Area

The study was executed in lower altitude zone below less than 900m above mean sea level in Chirpine Forest of Sirmaur District. Total three sites were selected for the study out of which two sites were dominated by invasive alien plant species i.e. Dhon dominated by *Ageratum conyzoides* in Nahan Forest Division and site Samon Kanon dominated by *Ageratina adenophora* in Paonta Forest Division. The third site was taken for comparison i.e. Sarlimanpur in Renuka Ji Forest Division and it was not dominated by invasive species i.e. *Ageratum conyzoides* and *Ageratina adenophora*. *Heteropogon contortus* was dominant species at Sarlimanpur. The sites without *Ageratum conyzoides* and *Ageratina adenophora* was not found below 900 m altitude zone in chirpine forest during reconnaissance survey. The detail of the study sites has been given in Table 1 and Fig. 1. The area of two hectare per site was selected in each site.

(i) Burning. The controlled burning was conducted in 1.50 hectare in three sites (B) in last week of February, 2017 and 0.50 hectare was kept as control (C) in each site.

(ii) Field sampling & data collection. The phyto-sociological data was collected in November, 2017 for control (C) as well as burnt (B). The quadrates of size 1×1 m^2 were used for collection of data. Total numbers of 40 quadrates were laid out in C and B. The natural regeneration of shrubs & trees were also included in phyto-sociological analysis.

(iii) Data analysis. The density, frequency, abundance and IVI (Importance value Index) were analyzed as per Curtis & Mcintoch, 1950. IVI was calculated by sum of relative value of density, basal area and frequency. Abundance to frequency was determined by Curtis & Cottom (1956) the ratio effect of regular (<0.050), (random 0.025 to 0.050) and contiguous (>0.050). The plant diversity was calculated by using Shanonn – Wiener diversity index (H) (Shanonn - Wiener, 1963)

$$H = -1X\sum_{i=1}^{S}(ni/N)\ln (ni/N)$$

Where ni= Importance value of species i and N= Total importance value of all the species in both the indices

Richness Index (R) was determined by formula (Margalef, 1958).

$$R = S\text{-}1/\ln N$$

Evenness index (E) was calculated by using following formula (Hill, 1973)

$$E = H/In\ S,$$

(iv) Statistical analysis. Independent samples t- test was used for determination of the significance of difference between the means of number of individuals/m^2 of ground flora of control (C) and burnt (B) treatments after controlled burning (Goulden, 1956). Total 40 quadrates were laid out for recording number of individuals/m^2. The mean of 04 quadrates were taken as one observation and total 10 observations was used to determine the significance difference between control (C) and burnt (B) sites.

Table 1: The geo–coordinates and other details of selected study sites in chirpine forests in Sirmaur District, Himachal Pradesh.

Sr. No.	Name of the Site	Name of Beat	Name of Forest Range	Geo-coordinates		Elevation (m)
				Latitude (N)	Longitude (E)	
1.	Samonkanon	Bharog Bhaneri	Girinagar	N 30˚33´38.2″	E 077˚31´21.0″	886
2.	Dhon	Dhon	Nahan	N 30˚33´09.4″	E 077˚21´03.9″	773
3.	Sarlimanpur	Jamna	Kafota	N 30˚38´32.5″	E 077˚45´13.7″	854

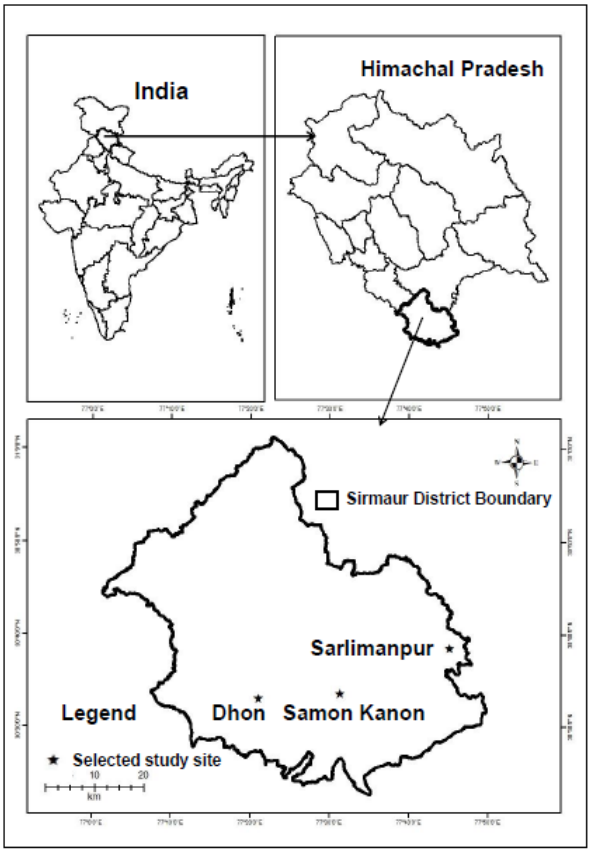

Fig. 1. Map of selected study sites in District Sirmaur in Himachal Pradesh.

III. RESULT AND DISCUSSION

The literature on impact of controlled burning on invasive plant species communities was not found much for supporting in writing the discussion in the present research paper in chir pine forest landscapes. The most efficient and cost effective method is to prevent biological invasion at early stage (Brunel *et al*., 2013 and Chawdhary *et al*., 2019). Growing season burn has more pronounced impact than dormant season of burning (Rice & Smith, 2008). The phyto-sociological analysis of *Ageratum conyzoides* community at site-Dhon, *Ageratina adenophora* at site-Samon Kanon and *Heteropogaon contortus* community at site-Sarlimanpur has been explained below:

Total number of species ranged from 18 to 24 in control (C) and 21 to 25 in burnt (B) sites. Total 18 and 21 species were present in control (C) and burnt (B) at Samonkanon, respectively whereas at Dhon, total number of species were 17 and 23 in control (C) and burnt (B), respectively. Total 24 and 25 species were present in control (C) and burnt (B) at Sarlimanpur, respectively.

(i) Density (Ind./m^2)

Ageratina adenophora (21.98) showed highest value for density/m^2 and least dominant was *Carissa carandas* (0.18) and *Pinus roxburghii* (0.18) in control (C) at Samon Kanon (Table 2) whereas in burnt (B) site at Samonkanon, *Ageratina adenophora* (41.45) showed highest value for density/m^2 and least dominant (0.25) was *Lantana camara* (Table 2). Significant difference was found in number of individual/m^2 between C (43.70) and B (74.88) at Samon Kanon (Calculated t = 8.00 and tabulated t = 2.10). The burning of invasive herbs can decrease the competition among individual and helpful in establishment of desirable species (DiTomaso, 2006; Goodrich and Rooks, 1999). The distribution of *Ageratina adenophora* in Himalayas has also been reported by various researchers (Ahmad *et al*., 2018; Bhardwaj and Kapoor, 2017; Chaudhary *et al*., 2019; Datta *et al*., 2017; Pathak *et al*., 2019 and Sekar *et al*., 2015).

Ageratum conyzoides (24.98) showed highest value for density/25m^2 and least dominant (0.23) was *Pinus roxburghii, Cassia fistula* and *Fragaria vesca* in control (C) at Dhon (Table 2). *Ageratum conyzoides* (39.63) showed highest value for density/25m^2 and least dominant (0.30) was *Dicliptera bupleuroides* in burnt (B) site (Table 2). Significant difference was found in number of individuals/m^2 between C (34.48) and B (55.60) at Dhon (Calculated t = 4.81 and tabulated t = 2.10). The invasion of *Ageratum conyzoides* has also been reported in Himachal Pradesh by Dogra *et al*. (2009); Dogra *et al*. (2008); Kaur *et al*. (2012); Kohli *et al*. (2004); Shekhar and Anju (2014).

Heteropogon contortus (13.38) showed highest value for density/m^2 *Chrysopogon montanus* (4.00) and least dominant (0.05) was recorded for *Achyranthes aspera* in control (C) at Sarlimanpur (Table 2). *Heteropogon contortus* (10.75) showed highest value for density/m^2 and least dominant (0.13) was recorded for *Cissampelos pareira* in burnt (B) site (Table 2). Significant difference was found in number of individual of herbs/m^2 between C (30.28) and B_1 (36.15) at Sarlimanpur (Calculated t = 2.35 and tabulated t = 2.10). The results are in line with Kumar *et al*. (2020a and b) for non invasive plant dominant community at Sarlimanpur.

(ii) Frequency (%)

Maximum frequency % was observed (100.00) for *Ageratina adenophora* and minimum value (5.00) was recorded for *Mallotus philippensis* and *Pinus roxburghii* in control (C) at site Samonkanon whereas in burnt (B) highest frequency % was observed (100.00) for *Ageratina adenophora* and lowest value (7.50) was recorded for *Lantana camara* at site Samonkanon (Table 3). Maximum frequency % was 97.50 for *Ageratum conyzoides* and minimum value (5.00) was observed for *Carrisa carandas, Dicliptera bupleuroides, Fragaria vesca, Hydrocotyl asiatica* and *Pinus roxburghii* in control (C) at site Dhon and in burnt (B) highest frequency % was 100.00 for

Ageratum conyzoides and lowest value (10.00) was observed for *Cassia fistula, Cheilanthes farinosa, Flacourtia indica, Hydrocotyle asiatica, Leucas lanata, Mallotus philippensis, Murraya koenigii, Viola serpens* and *Pinus roxburghii* at site Dhon (Table 3).

Table 2: Density (Ind./m^2) of species in control (C) and burnt (B) sites.

Sr. No.	Name of species	Samonkanon		Dhon		Sarlimanpur	
		C1	B	C	B	C	B
1.	*Achyranthes aspera* L.					0.05	0.25
2.	*Adiantum lunulatum* Burm.f.	1.05	1.58	0.50	0.63	1.40	2.05
3.	*Ageratina adenophora* (Spreng.) R.M.King & H. Rob.	21.98	41.45	0.95	0.63	0.55	1.78
4.	*Ageratum conyzoides* (L.) L.	3.00	3.38	24.98	39.63	0.28	1.55
5.	*Ajuga bracteosa* Wall. ex Benth.	0.23					
6.	*Bidens pilosa* L.		0.55				
7.	*Carissa carandas* L.**	0.18	0.45	0.25	0.50		
8.	*Cassia fistula* L.*	0.20	0.65	0.23	0.40		
9.	*Cheilanthes farinosa* (Forssk.) Kaulf	0.25	0.55		0.40	0.50	1.40
10.	*Chrysopogon gryllus* (L.) Trin.					2.50	3.75
11.	*Chrysopogon montanus* Trin.	2.65	6.05	2.30	3.40	4.00	3.38
12.	*Ciissampelos pareira* L.			0.28	0.60	0.08	0.13
13.	*Cynodon dactylon* (L.) Pers.		2.33				
14.	*Cynoglossum foliolossum* Paine					0.13	0.15
15.	*Dicliptera bupleuroides* Nees	0.53	0.75	0.25	0.30	0.28	1.53
16.	*Erigeron vulgaris* Scheele ex Nyman					0.58	0.20
17.	*Eulaliopsis binata* (Retz.) C.E.Hubb.	3.00	4.20			0.38	0.88
18.	*Euphorbia hirta* L.		0.55			0.13	0.65
19.	*Fragaria vesca* L.	0.75	0.55	0.23	0.40	0.75	0.85
20.	*Flacourtia indica* (Burm.f.) Merr.*				0.60	0.20	0.28
21.	*Galium aparine* L.				0.48		0.20
22.	*Geranium* sp.					0.10	0.23
23.	*Girardinia heterophylla* Decne.					0.05	0.23
24.	*Heteropogon contortus* (L.) P.Bewauv. ex. Roem. & Schult.	2.28	4.23	2.13	3.30	13.38	10.75
25.	*Hydrocotyle asiatica* L.			0.30	0.55		
26.	*Lantana camara* L.**	0.38	0.25				
27.	*Leucas lanata* Benth.				0.40	0.10	0.15
28.	*Mallotus philippensis* (Lam.) Mull.Arg.*	0.20	0.58	0.33	0.35		
29.	*Malvestrum tricuspidatum* A. Gray					0.33	0.15
30.	*Murraya koenigii* (L.) Spreng.**	0.48	0.55	0.45	0.55		
31.	*Oxalis corniculata* L.	2.28	2.55	0.50	0.60	1.80	4.13
32.	*Pinus roxburghii* Sarg.*	0.18	0.65	0.23	0.33	0.20	0.43
33.	*Pyrus pashia* Buch.-Ham. ex D.Don *		0.50	0.30	0.40	0.30	0.48
34.	*Shorea robusta* Gaertn.*			0.30	0.40		
35.	*Sonchus asper* (L.) Hill				0.43		
36.	*Themeda anathera* (Nees es Steud.) Hack.	4.13	2.55				
37.	*Viola serpens* Wall. ex Ging.				0.35	2.25	0.63
	Total	**43.75**	**74.9**	**34.51**	**55.63**	**30.32**	**32.21**

Table 3: Frequency per cent of species in control (C) and burnt (B) sites.

S. No.	Name of species	Samonkanon		Dhon		Sarlimanpur	
		C	B	C	B	C	B
1.	*Achyranthes aspera* L.					5.00	12.50
2.	*Adiantum lunulatum* Burm.f.	17.50	20.00	10.00	22.50	7.50	22.50
3.	*Ageratina adenophora* (Spreng.) R.M.King & H. Rob.	100.00	100.00	15.00	15.00	10.00	20.00
4.	*Ageratum conyzoides* (L.) L.	37.50	25.00	97.50	100.00	5.00	15.00
5.	*Ajuga bracteosa* Wall. ex Benth.	7.50					
6.	*Bidens pilosa* L.		15.00				
7.	*Carissa carandas* L.**	10.00	12.50	5.00	12.50		
8.	*Cassia fistula* L.*	7.50	12.50	7.50	10.00		
9.	*Cheilanthes farinosa* (Forssk.) Kaulf	12.50	15.00		10.00	5.00	20.00
10.	*Chrysopogon gryllus* (L.) Trin.					47.50	10.00
11.	*Chrysopogon montanus* Trin.	40.00	67.50	30.00	47.50	65.00	12.50
12.	*Ciissampelos pareira* L.			10.00	15.00	7.50	5.00
13.	*Cynodon dactylon* (L.) Pers.		27.50				
14.	*Cynoglossum foliolossum* Paine					7.50	5.00
15.	*Dicliptera bupleuroides* Nees	10.00	20.00	5.00	15.00	5.00	17.50
16.	*Erigeron vulgaris* Scheele ex Nyman					5.00	12.50
17.	*Eulaliopsis binata* (Retz.) C.E.Hubb.	37.50	50.00			5.00	12.50
18.	*Euphorbia hirta* L.		20.00			5.00	15.00
19.	*Fragaria vesca* L.	15.00	17.50	5.00	10.00	5.00	12.50
20.	*Flacourtia indica* (Burm.f.) Merr.*				15.00	7.50	10.00
21.	*Galium aparine* L.				12.50		10.00
22.	*Geranium* sp.					5.00	12.50
23.	*Girardinia heterophylla* Decne.					5.00	12.50
24.	*Heteropogon contortus* (L.) P.Bewauv. ex. Roem. & Schult.	40.00	62.50	25.00	45.00	70.00	65.00
25.	*Hydrocotyle asiatica* L.			5.00	10.00		
26.	*Lantana camara* L.**	12.50	7.50				
27.	*Leucas lanata* Benth.				10.00	5.00	10.00
28.	*Mallotus philippensis* (Lam.) Mull.Arg.*	5.00	12.50	7.50	10.00		
29.	*Malvestrum tricuspidatum* A. Gray					15.00	12.50
30.	*Murraya koenigii* (L.) Spreng.**	10.00	17.50	10.00	10.00		
31.	*Oxalis corniculata* L.	40.00	30.00	10.00	15.00	17.50	65.00
32.	*Pinus roxburghii* Sarg.*	5.00	12.50	5.00	10.00	7.50	15.00
33.	*Pyrus pashia* Buch.-Ham. ex D.Don *		10.00	7.50	12.50	7.50	15.00
34.	*Shorea robusta* Gaertn.*			7.50	12.50		
35.	*Sonchus asper* (L.) Hill				12.50		
36.	*Themeda anathera* (Nees es Steud.) Hack.	30.00	40.00				
37.	*Viola serpens* Wall. ex Ging.				10.00	20.00	10.00

Maximum frequency % was observed for *Heteropogon contortus* (70.00) and minimum value (5.00) was recorded for *Achyranthes aspera*, *Ageratum conyzoides*, *Cheilanthes farinosa*, *Dicliptera bupleuroides*, *Erigeron vulgare*, *Eulaliopsis binata*, *Euphorbia hirta*, *Fragaria vesca*, *Geranium* sp., *Girardinia heterophylla* and *Leucas lanata* in control (C) at site Sarlimanpur whereas in burnt (B) highest frequency % was observed (65.00) for *Heteropogon contortus* and *Oxalis corniculata* and lowest value was recorded (5.00) for *Cissampelos pareira* and *Cynoglossum foliolossum* at site Sarlimanpur (Table 3).

(iii) Abundance (A)

Maximum abundance (21.98) was observed for *Ageratina adenophora* and minimum value (1.75) was observed for *Carissa carandas* in control (C) at site Samonkanon whereas maximum abundance (41.45) was observed for *Ageratina adenophora* and minimum value (2.75) was observed for *Euphorbia hirta* in burnt (B) at site Samonkanon (Table 4).

Maximum abundance was observed for *Ageratum conyzoides* (25.62) and minimum value (2.75) were observed for *Cissampelos pareira* in control (C) at site Dhon (Table 4), whereas in burnt (B) site, maximum abundance was observed for *Ageratum conyzoides* (39.63) and minimum value (2.00) were observed for *Dicliptera bupleuroides* at site Dhon (Table 4).

Maximum abundance (19.11) was observed for *Heteropogon contortus* and minimum value (1.00) was observed for *Achyranthes aspera* and *Girardinia heterophylla* in control (C) at site Sarlimanpur whereas maximum abundance (37.50) was observed for *Chrysopogon gryllus* and minimum value (1.20) was observed for *Malvestrum tricuspidatum* in burnt (B) at site Sarlimanpur (Table 4). The results are in line with Kumar *et al*. (2020a).

(iv) Importance Value Index (IVI)

Ageratina adenophora (93.93) was dominant species on the basis of IVI and least dominant (4.32) was *Pinus roxburghii* in control (C) at site Samonkanon (Table 5) whereas in burnt (B) *Ageratina adenophora* (85.63) was dominant species on the basis of IVI and least dominant (4.46) was recorded for *Cheilanthes farinosa* at site- Samonkanon (Table 5).

Ageratum conyzoides (112.22) was dominant species on the basis of IVI and least dominant (5.37) was *Pinus roxburghii* in control (C) at site Dhon (Table 5) whereas in burnt (B) *Ageratum conyzoides* (102.24) was dominant species on the basis of IVI and least dominant (4.39) was *Mallotus philippensis* at site Dhon (Table 5).

Heteropogon contortus (69.59) was dominant species on the basis of IVI and least dominant (3.40) was recorded for *Girardinia heterophylla* in control (C) at site Sarlimanpur (Table 5) whereas in burnt (B) site, *Heteropogon contortus* (47.88) was dominant species on the basis of IVI and least dominant (3.70) was recorded for *Leucas lanata* at site Sarlimanpur (Table 5). Similar results were also reported by Kumar *et al*. (2020b).

Table 4: Abundance of species in control (C) and burnt (B) sites.

S. No.	Name of species	Samonkanon		Dhon		Sarlimanpur	
		C	B	C	B	C	B
1.	*Achyranthes aspera* L.					1.00	2.00
2.	*Adiantum lunulatum* Burm.f.	6.00	7.88	5.00	2.78	18.67	9.11
3.	*Ageratina adenophora* (Spreng.) R.M. King & H. Rob.	21.98	41.45	6.33	4.17	5.50	8.88
4.	*Ageratum conyzoides* (L.) L.	8.00	13.50	25.62	39.63	5.50	10.33
5.	*Ajuga bracteosa* Wall. ex Benth.	3.00					
6.	*Bidens pilosa* L.		3.67				
7.	*Carissa carandas* L.**	1.75	3.60	5.00	4.00		
8.	*Cassia fistula* L.*	2.67	5.20	3.00	4.00		
9.	*Cheilanthes farinosa* (Forssk.) Kaulf	2.00	3.67		4.00	10.00	7.00
10.	*Chrysopogon gryllus* (L.) Trin.					5.26	37.50
11.	*Chrysopogon montanus* Trin.	6.63	8.96	7.67	7.16	6.15	27.00
12.	*Ciissampelos pareira* L.			2.75	4.00	1.00	2.50
13.	*Cynodon dactylon* (L.) Pers.		8.45				
14.	*Cynoglossum foliolossum* Paine					1.67	3.00
15.	*Dicliptera bupleuroides* Nees	5.25	3.75	5.00	2.00	5.50	8.71

S. No.	Name of species	Samonkanon		Dhon		Sarlimanpur	
		C	B	C	B	C	B
16.	*Erigeron vulgaris* Scheele ex Nyman					11.50	1.60
17.	*Eulaliopsis binata* (Retz.) C.E.Hubb.	8.00	8.40			7.50	7.00
18.	*Euphorbia hirta* L.		2.75			2.50	4.33
19.	*Fragaria vesca* L.	5.00	3.14	4.50	4.00	15.00	6.80
20.	*Flacourtia indica* (Burm.f.) Merr.*				4.00	2.67	2.75
21.	*Galium aparine* L.				3.80		2.00
22.	*Geranium* sp.					2.00	1.80
23.	*Girardinia heterophylla* Decne.					1.00	1.80
24.	*Heteropogon contortus* (L.) P.Bewauv. ex. Roem. & Schult.	5.69	6.76	8.50	7.33	19.11	16.54
25.	*Hydrocotyle asiatica* L.			6.00	5.50		
26.	*Lantana camara* L.**	3.00	3.33				
27.	*Leucas lanata* Benth.				4.00	2.00	1.50
28.	*Mallotus philippensis* (Lam.) Mull.Arg.*	4.00	4.60	4.33	3.50		
29.	*Malvestrum tricuspidatum* A. Gray					2.17	1.20
30.	*Murraya koenigii* (L.) Spreng.**	4.75	3.14	4.50	5.50		
31.	*Oxalis corniculata* L.	5.69	8.50	5.00	4.00	10.29	6.35
32.	*Pinus roxburghii* Sarg.*	3.50	5.20	4.50	3.25	2.67	2.83
33.	*Pyrus pashia* Buch.-Ham. ex D.Don *		5.00	4.00	3.20	4.00	3.17
34.	*Shorea robusta* Gaertn.*			4.00	3.20		
35.	*Sonchus asper* (L.) Hill				3.40		
36.	*Themeda anathera* (Nees es Steud.) Hack.	13.75	6.38				
37.	*Viola serpens* Wall. ex Ging.				3.50	11.25	6.25

Table 5: Importance Value Index (IVI) of species in control (C) and burnt (B) sites.

S. No.	Name of species	Samonkanon		Dhon		Sarlimanpur	
		C	B	C	B	C	B
1.	*Achyranthes aspera* L.					10.08	10.00
2.	*Adiantum lunulatum* Burm.f.	12.98	9.60	11.92	10.57	10.52	14.54
3.	*Ageratina adenophora* (Spreng.) R.M.King & H. Rob.	93.93	85.63	20.81	11.09	5.99	13.82
4.	*Ageratum conyzoides* (L.) L.	19.47	10.24	112.22	102.24	6.05	13.16
5.	*Ajuga bracteosa* Wall. ex Benth.	10.30					
6.	*Bidens pilosa* L.		8.83				
7.	*Carissa carandas* L.**	5.92	5.31	5.90	9.38		
8.	*Cassia fistula* L.*	8.48	10.03	6.19	4.65		
9.	*Cheilanthes farinosa* (Forssk.) Kaulf	6.66	4.46		5.55	6.49	14.93
10.	*Chrysopogon gryllus* (L.) Trin.					27.64	15.41
11.	*Chrysopogon montanus* Trin.	17.91	19.75	20.73	18.32	33.91	15.88
12.	*Ciissampelos pareira* L.			11.00	5.94	10.47	9.10
13.	*Cynodon dactylon* (L.) Pers.		8.77				
14.	*Cynoglossum foliolossum* Paine					5.97	5.83
15.	*Dicliptera bupleuroides* Nees	14.49	7.99	10.89	6.59	6.08	12.29

16.	*Erigeron vulgaris* Scheele ex Nyman					9.85	9.47
17.	*Eulaliopsis binata* (Retz.) C.E.Hubb.	19.47	14.14			8.31	9.55
18.	*Euphorbia hirta* L.		5.30			5.62	9.35
19.	*Fragaria vesca* L.	7.74	4.75	13.71	4.43	10.02	8.61
20.	*Flacourtia indica* (Burm.f.) Merr.*				5.94	8.08	5.86
21.	*Galium aparine* L.				5.66		8.26
22.	*Geranium* sp.					5.51	6.20
23.	*Girardinia heterophylla* Decne.					3.40	9.97
24.	*Heteropogon contortus* (L.) P. Bewauv. ex. Roem. & Schult.	15.18	16.78	18.87	18.49	69.59	47.88
25.	*Hydrocotyle asiatica* L.			10.21	13.27		
26.	*Lantana camara* L.**	10.91	11.00				
27.	*Leucas lanata* Benth.				9.06	4.45	3.70
28.	*Mallotus philippensis* (Lam.) Mull.Arg.*	6.47	13.04	8.74	4.39		
29.	*Malvestrum tricuspidatum* A. Gray					6.62	6.93
30.	*Murraya koenigii* (L.) Spreng.**	6.15	18.31	19.90	13.27		
31.	*Oxalis corniculata* L.	15.18	9.16	10.20	5.94	12.18	27.44
32.	*Pinus roxburghii* Sarg.*	4.32	11.76	5.37	9.42	7.59	5.61
33.	*Pyrus pashia* Buch.-Ham. ex D.Don *		14.43	6.54	7.70	11.16	9.06
34.	*Shorea robusta* Gaertn.*			6.81	9.20		
35.	*Sonchus asper* (L.) Hill				10.16		
36.	*Themeda anathera* (Nees es Steud.) Hack.	24.44	10.72				
37.	*Viola serpens* Wall. ex Ging.				8.74	14.41	7.13

(v) Diversity indices

(a) Distribution pattern of species

The distribution pattern of species was contiguous as per the ratio of A/F for herbs in control as well as burnt areas in each site. The contiguous distribution pattern has also been reported by (Kumar *et al*., 2020c & Kumar *et al*., 2020d).

(b) Diversity index (H)

The maximum value of diversity index (H) was 3.03 in burnt (B) site at Sarlimanpur followed by 2.81 in burnt (B) at Sarlimanpur and minimum (2.33) at Dhon (Table 6, Fig. 2). The beneficial impact of burning has also been reviewed by Kumar (2019).

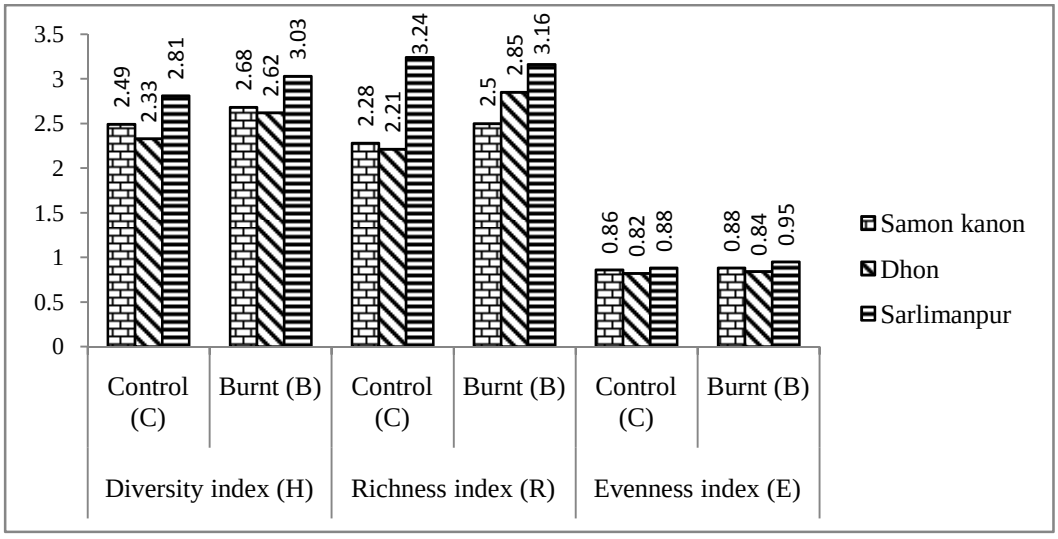

Fig. 2. Diversity index (H), richness index (R) and evenness index (E) in selected control (C) and burnt (B) sites.

Table 6: Diversity index (H), richness index (R) and evenness index (E) in control (C) and burnt (B) sites.

Sr. No.	Name of Site	Diversity index (H)		Richness index (R)		Evenness index (E)	
		C	B	C	B	C	B
1.	**Samon kanon**	2.49	2.68	2.28	2.50	0.86	0.88
2.	**Dhon**	2.33	2.62	2.21	2.85	0.82	0.84
3.	**Sarlimanpur**	2.81	3.03	3.24	3.16	0.88	0.95
	Mean	2.54	2.78	2.58	2.84	0.85	0.89

(c) Species richness index (R)

The highest value of (3.24) of species richness index (R) was recorded at control (C) site at Sarlimanpur followed by 3.16 in burnt (B) site at Sarlimanpur and lowest was 2.21 in control (C) at Dhon (Table 6, Fig. 2).

(d) Evenness index (E)

The evenness index (E) was maximum (0.95) in burnt (B) at Sarlimanpur followed by 0.88 in control (C) at Sarlimanpur as well as at burnt (B) and minimum was 0.82 in control (C) at Dhon (Table 6, Fig. 2). Although it is very complex interactions among controlled burning, chirpine forest ecosystem and invasive alien plant species. The burning effect the composition as well as structure of plant community forming complex relationship between invaded species and fire (Garcia *et al*., 2015 and Mandle *et al*., 2011). The invasive alien plant species prefer the degraded and disturbed areas. The total density of the herbs were significantly higher in burnt site as compared to control sites. The positive impact of early summer burning or late spring burning on native and non-native forb species has also been reported by DiTomos *et al.,* (1999) and DiTomaso *et al*., (1998).

The clear cut trend on impact of controlled burning on abundance and frequency per cent was not found on ground flora which is also supported by Kumar, *et al*. (2020a). The diversity was higher in burnt sites in *Ageratum conyzoides*, *Ageratina adenophora* and *Heteropogon contortus* dominant communities. The diversity index (H) and evenness index (E) were higher in burnt (B) sites as compared to control (C). The higher diversity of invasive alien plant species after burning was recorded by Floyd *et al*. (2006) and Eales *et al*., (2018) as well as also reported enhancement in the plant richness. The controlled burning is used to decrease the biomass fuel load and to increase biodiversity (Ditomoso *et al*., 2006b). Controlled burning can be used to decrease the dominance of invasive alien plant species and to increase the diversity in chirpine forest. The literature on impact of controlled burning on invasive species in chirpine forests was not found. The controlled burning decrease the chances of forest fire in chirpine forest. The controlled burning is one of the tool to reduce the fuel load. There is need to manage the areas invaded by alien plant species at present because it will further degrade the areas and decrease the diversity in future.

The controlled burning is one of technique which can be tested at various locations to enhance the diversity in the landscapes which are invaded by invasive alien plant species.

CONCLUSIONS

The controlled burning increased the density and diversity in invasive as well as non-invasive herbaceous dominant communities. The impact of controlled burning on abundance and frequency (%) did not show clear cut trend.

ACKNOWLEDGEMENTS

The author is thankful to Director, HFRI, Shimla for giving permission to execute the study and also thankful to Himachal Pradesh Forest Department for assisting in the field activities of the project. The author is also thankful to ICFRE Dehradun for funding the research work and to Mrs. Shilpa, Sh. Dushyant, Sh. Kulwant Rai Gulshan, Sh. Vikas Kumar, Miss Krishna Kumari and Sh. Pankaj Sharma for helping in study.

REFERENCES

Ahmad, M., Uniyal, S.K.R., and Singh, R.D. (2018). Pattern of alien plant species richness across gradients of altitude: Analyses from the Himalayan state of Himachal Pradesh. *Tropical Ecology*, **59**(1): 35-43.

Anderson, S. (2005). Spread of the introduced tree species *Prosopis juliflora* (Sw) DC in the lake Baringo area, Kenya. Institutional for Skoglif Vegetationsekologi, SLu (Swedish Agricultural University), UMEA, Sweden.

Andreasen, C., Rossing, K. and Ritz, C. (2020). Prescribed burning as a management tool to destroy dry seeds of invasive conifers in heathland in Denmark. *Land*. **9**(11): 432. (https://doi.org/10.3390/land9110432)

Batish, D.R. (2008). Tropical American invasive weeds in the Shiwalik Range of North Western Himalayas of India: An assessment of status and impact. Available online at

http,//www.apafri.org/forestHelath08/DAY2_Forest%20Health%20Workshop/Daizy_APAFRI_DAIZY_Malaysia-1.pdf (accessed 18 October 2009).

Batish, D.R. Kaur, S., Singh, H.P. and Kohli, R.K. (2009a). Role of root-mediated interactions in phytotoxic interference of *Ageratum conyzoides* with rice (*Oryza sativa*). *Flora*, **204**: 388-395.

Batish, D.R., Kaur, S., Singh, H.P. and Kohli, R.K. (2009b). Nature of interference potential of leaf debris of *Ageratum conyzoides*. *Plant Growth Regulation*, **57**: 137-144.

Bhardwaj, S. Kapoor, K.S. and Singh, H.P. (2014). Studies on alleophatic effects of *Ageratina adenophora* Sprengel. (King and Robinson) on some weeds plants growing in forest ecosystem. *International Journal of Theoretical and Applied Sciences*, **6**(2): 1-6.

Bhardwaj, S. and Kapoor, K.S. (2017). *Ageratina adenophora*: Its invasion and influence on the biodiversity of herbaceous vegetation in Girinagar range of Paonta Forest Division, district Sirmour, Himachal Pradesh. *Environment and Ecology*, **35**(4B): 3113-3117.

Brunel, S., Galiano, E.F., Piero Genovesi, E., Vernon, H., Heywood, V.H. and Kueffer, C.A. (2013). Invasive alien species: A growing but neglected threat? In European Environment Agency (EEA), Denmark, Report (1/2013): Late lessons from early warnings: Science, precaution, innovation, 486-508.

Chaudhary, A., Adhikari, B.S., Joshi, N.C. and Rawat, G. S. (2019). Patterns of invasive by crofton weed (*Ageratina adenophora*) in Kailash sacred landscape region of western Himalaya (India). *Environment Conservation Journal*, **20**(3): 9-17.

Crawford, J.S, Wahren C.H.A., Kyle S, Moir, W.H. (2001). Responses of exotic plant species to fires in *Pinus ponderosa* forests in northern Arizona. *Journal of Vegetation Science*, **12**: 261-268.

Curtis, J.T. and Cottam, G. (1956). Plant ecology work book- laboratory field reference manual. Burgess Publishing Co., Minnesota. 193p.

Curtis, J.T. and Mclntosh, R.P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, **1**: 434-455.

Cushman, J.H. and Gaffeny, K.A. (2010). Community-level consequences of invasion, impacts of exotic clonal plants on riparian vegetation. *Biological Invasions*, **8**: 1073-1089

Datta, A., Kuhn, I., Ahmad, M., Michalski, S. and Auge, H. (2017). Process affecting altitudinal distribution of invasive *Ageratina adenophora* in Western Himalaya: The role of local adaptation and the importance of different life cycle stages. *Plos One*. **12**(11): https://doi.org/10.1371/journal.pone.0187708

DiTomaso, J.M. and D.W. Johnson (eds). (2006b). The use of fire as a tool for controlling invasive plants. Cal-IPC Publications 2006-01. California Invasive Plant Council: Berkely, CA.56 pp.

DiTomaso, J.M., Brooks, M.L., Allen, E.B., Minnich, R., Rice, P.M. and Kyser, G.B. (2006). Control of invasive weeds with prescribed burning, *Weed Technology*. **20**: 535-548.

DiTomaso, J.M., Kyser, G.B. and M.S. Hastings. (1999). Prescribed burning for control of yellow starthistle (*Centaurea solstitialis*) and enhanced native plant diversity. *Weed Science*, **47**: 233-242.

DiTomaso, J.M., W.T. Lanini, C.D. Thomsen, T.S. Prather, C. E. Turner, M.J. Smith, C. L. Elmore, M.P. Vayssieres and W.A. Williams (1998). Yellow Starthistle. Oakland, CA: University of California DANR Pest Notes, NO. 3.4 p.

Dogra, K.S. (2008). Impact of some invasive species on the structure and composition of natural vegetation of Himachal Pradesh. Ph.D. thesis, Punjab University, Chandigarh, India.

Dogra, K.S., Kohli, R.K., Sood, S.K. and Dobhal, P.K. (2009). Impact of *Ageratum conyzoides* L. on the diversity and composition of vegetation in the Shivalik hills of Himachal Pradesh (Northwestern Himalaya), India. *International Journal of Biodiversity* and *Conservation*, **1**(4): 135-145.

Eales, J., Haddaway, N.R., Bernes, C., Cooke, S.J., Jonsson, B.G., Koilo, J., Petrokofsky, G. and Taylor, J.J. (2018). What is the effect of prescribed burning in temperate and boreal forest on biodiversity, beyond pyrophilous and saproxylic species. A systematic review, *Environmental Evidence*, **7**: 19

Flory, S.L., Clay, K., Emery, S. and Robb, J. (2012). Fire and the invasive annual grass *Microstegium vimineum* in eastern deciduous forests. *JFSP Research Project Reports*. 79. University of Nebraska-Lincoln.

Floyd, M.L., Hanna, D., Romme, W.H. and Crews, T.E. (2006). Predicting and mitigating weed invasions to restore natural post-fire succession in Mesa Verde National Park, Colorado, USA. *International Journal of Wildland Fire*, **15**: 247-259.

Garcia, R.A., Engler, M.L., Pena, E., Pollnac, F.W. and Anibal Pauchard (2015). Fuel characteristics of the invasive shrub *Telin emonspessulana* (L.) K. Koch. *International Journal of Wildland Fire.* http://dx.doi.org/10.1071/WF13078

Goodell, K. (2008). Invasive exotic plant bee interactions In : James, R.R. and Pitts- Singer, T.L. (eds) Bee Pollination in agro-ecosystem. *Oxford University press, Oxford, UK*, pp. 166-183.

Goodrich, S. and Rooks, D. (1999). Control of weeds at a Pinyon-Juniper site by seeding grasses . In S. B. Monsen and R. Stevens, eds. Proceedings,

Ecology and Management of Pinyon-Juniper Communities within the Interior West, Provo, UT. RMES-P-9. Mountain Research Station. Ogden. UT: U.S. Department of Agriculture, Forest Service. Pp. 403-407.

Goulden, C. H. (1956). Methods of statistical analysis. 2nd ed. New York. Wiley. 50-55.

Griffis, K.L., Crawford, J.A., Wagner, M.R., Moir, W.H. (2001). Understory response to management treatments in northern *Arizona ponderosa* pine forests. *Forests Ecology and Management*, **146**, 239-245. doi : 10.1016/S0378-1127(00)00461-8

Hill, M.O. (1973). Diversity and its evenness, a unifying notation and its consequences. *Ecology*, **54**: 427-432.

Hobbs, R. and Humphries, S. (1995). An integrated approach to the ecology and management of plant invasions, *Conservational Biology*, **9**: 761-770.

Hunter, M.E., Omi, P.N., Martinson, E.J. and Chong, G.W. (2006). Establishment of non-native plant species after wildfires: Effects of fuel treatments, abiotic and biotic factors, and post-fire grass seeding treatments. *International Journal of Wildland fire*, **15**: 271-281.

Karl. K., Limb, R., Ganguli, A., Hovick. T., and Sedivec. K. (2018). Seasonal prescribed fire variation decreases inhibitory ability of *Poa pratensis* L. and promotes native plant diversity. *Journal of Environmental Management*, **223**: 908-916. (https://doi.org/10.1016/j.envman.2018.06.096)

Kaur, S., Batish, D.R., Kohli, R.K. and Singh, H.P. (2012). *Ageratum conyzoides*: An alien invasive weed in India. *An Ecological Appraisal for the Indian Subcontinent*, 57-75.

Kohli, R. K., Dogra, K.S., Batish, D.R. and Singh, H.P. (2004). Impact of invasive plants on structure and composition of natural vegetation of North western Indian Himalayas. *Weed Technology*, **18**: 1296-1300.

Kohli, R.K., Batish, D.R., Singh, H.P., Dogra, K.S. (2006). Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biological Invasions*, **8**: 1501-1510.

Keeley, J.E., Lubin D., Fortheringham, C.J. (2003). Fire and grazing impacts on plant diversity and alien plant invasions in southern Sierra Nevada. *Ecological Applications*, **13**: 1355-1374.

Keeley, J.E. (2000). Fire and invasive plants in Mediterranean-climate Ecosystems of California. In Galley, K.E.M.; Wilson, T.P., eds., Proceedings of the Invasive Species Workshop: The Role of fire in the control and spread of invasive species (Fire Conference 2000: The first National Congress on Fire Ecology, Prevention and Management; 2000 November 27-December 1; San Diego, CA), Misc. Pub. No. 11, Tallahassee, FL: Tall Timber Research Station: 81-94.

Kumar, R., Verma, R.K., Kumari, K., Kumar. V. and Gulshan, K.R. (2020a). Impact of controlled burning on herbs in high altitude zone of Chirpine Forests in Solan and Nahan Circles, Himachal Pradesh. *International Journal of Bio-resource and Stress Management*, **11**(4): 414-424.

Kumar, R., Verma, R. K., Kumar, S., Thakur, C., Prakash, R., Kumari, K., Dushyant and Yadav, S. (2020c). Diversity of herbs in Kibber Wildlife Sanctuary of Distt. Lahaul and Spiti. *Biological Forum-An International Journal*, **12**(2): 01-12.

Kumar, R., Verma, R.K., Thakur, C., Prakash, R. and Kumar, S. (2020b). Diversity of shrubs in Kibber beat in Kibber Wildlife Sanctuary of Lahaul & Spiti District, Himachal Pradesh. *International Journal of Theoretical & Applied Sciences*, **12**(2): 01-08.

Kumar, R., Verma, R.K., Kumari, K., Kumar, V. and Prakash, R. (2020b). Impact of burning in winter on diversity of ground flora after monsoon period in mid altitude Chirpine zone of Nahan circle of Himachal Pradesh. *International Journal of Advanced Research in Biological Sciences*, **7**(11): 1-11.

Kumar, R. (2019). Prescribed burning: An important tool in management of forest resources. *Indian Journal of Forestry*, **42**(2): 123-131.

Mandle, L., Bufford, J.K., Schmidt, I.B. Daehler, C. (2011). Woody exotic plant invasions and fire: Reciprocal impacts and consequences for native ecosystems. *Biological Invasions* 13, 1815-1827. doi:10.1007/S10530-011-0001-3

Margalef, R. (1958). Temporal succession and spatial heterogeneity in phyto-plankton. In: A. Buzzati-Traverso. (Ed.). *Perspective in Marine Biology*. University of California Press, Berkeley, 323-347.

Okunade, A.L. (2002). *Ageratum conyzoides* L. (Astreraceae). *Fitoterapia*, **73**: 1-16.

Panse, V. G. and Sukhatme, (1967). Statistical methods for agriculture workers – New Delhi. ICAR. 610p.

Pathak, R., Negi, V.S., Rawal, R.S. and Bhatt, I.D. (2019). Alien plant invasion in the Indian Himalayan Region: State of knowledge and research priorities. *Biodiversity and Conservation*. **28**(7). https://doi.org/10.1007/s10531-019-01829-1

Pollak, O. and Kan, T. (1998). The use of prescribed fire control invasive exotic weeds at Jepson Prairie Preserve. *Ecology Conservation and Management*, 241-249.

Pyke, D.A., Wirth, T.A. and Beyers, J.L. (2013). Does seeding after wildfires in rangelands reduce erosion or invasive species? *Restoration Ecology*, **21**(4): 415-421.

Rice, P.M and Smith, J.K. (2008). Use of fire to manage populations of nonnative invasive plants.

In Zouhar, Kristin; Smith, Jane Kapler; Sutherland, Steve; Brooks, Matthew L. Wildland fire in ecosystems: Fire and nonnative invasive plants. Gen. Tech. Rep. RMRS-GTRE-42-vol. 6. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 47-60.

Sekar, K.C., Pandey, A., Srivastava, S.K. and Giri, L. (2015). Invasive alien plants of Himachal Pradesh, India. *Indian Forester*, **141**(5): 520-527.

Shekhar, T.C. and Anju, G. (2014). Antioxidant activity by DPPH radical scavenging method of *Ageratum conyzoides* Linn. leaves. *American Journal of Ethnomedicine*, **1**(4): 244-249.

Shannon, C.E. and Wiener, W. (1963). The Mathematical Theory of Communication. Univ. of Illinois Press. Urbana, U.S.A.

Van Wilgen, B.W. (2009). The evolution of fire and invasive alien plant management practices in fynbos. *South African Journal of Science*, **105**: 335-342.

Vale, T.R., ed. (2002). Fire, Native Peoples, and the Natural landscape. Washington, DC: Island Press. 238 p.

Weidenhmer, J.D. and Callaway, R. M. (2010). Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. *Journal of Chemical Ecology*, **36**: 59-69.

Zouhar, K., Smith, J.K., Sutherland, S. and Brooks, M.L. (2008). Wildland fire in Ecosystems fire and nonnative plants. USDA Forest Service Rocky Mountain Research Station General Technical Report (RMRS-GTR-42(6): 1-7.

How to cite this article: Kumar, R. (2021). Studying the Effect of Controlled Burning on Invasive Plant Dominant Communities in Lower Altitude Chirpine Forests in Sirmaur District, Himachal Pradesh. *Biological Forum – An International Journal*, **13**(1): 312-323.