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**ARTICLE**

# Burning Frequency Influences Plant Composition and Diversity and Mycorrhizal Spore Density in a Lateritic Dry Deciduous Sal Dominated Forest

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## ABSTRACT

Burning in forest floor, specially, in deciduous forests is an annual practice of forest dwellers in some states of India to collect non timber forest produce at ease. Sometimes this springtime burning get out of control and damage the forest severely. Sal dominated mixed forest in Godapyasal range, Midnapore division, West Midnapore in south West Bengal, with different fire incidence histories was taken for the study. An intensive survey of sites with regular burning, occasional burning and no burning were done to study plant diversity and community composition and the results were compared within different sites. Severe burning regimes damaged the plant density drastically rendering the saplings of subdominants only near ground level as coppice. Mild fire frequencies, though not severely damaged plant community, differed from unburned area significantly. Fire hardy tree species are dominant and subdominant in both sites. In severe burned site, plant diversity increased with a number of invasive perennials and annuals and spiny undershrubs and show even distribution. Common plants in the three communities were observed to be affected in their community parameters with burning frequency. Frequent and occasional burning both reduced mycorrhizal population with larger spores drastically and not replaced even after nine months of burning. AMF with smaller spores are less affected.

***Keywords:*** Arbuscular Mycorrhizae; Burning frequency; Diversity; Dry deciduous forest; Forest fire; Plant community; Spore density.

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# 1. Introduction

India contributes 2% to the worldwide total forest cover [1] and is the second most vulnerable country to forest fires in south Asia [2]. Deciduous forests in India are prone to forest fire onward of spring. During dry season, the forest floor became covered with litter, which burst into rapid uncontrollable flames by the smallest source of ignition comes into contact. High atmospheric temperatures and low humidity offer favourable circumstance for a fire to start. Forest fires are mostly manmade in this type of forest [3]. Human population depended on forest for livelihood intentionally initiate burning sometimes, with the belief that fire will help better regeneration of plants and mushroom, increase plant productivity; reduce snake population and collection of non-timber forest produces (NTFP) and firewood would be easier. Annually, 3.73 Mha in Indian forest areas experience forest fires, the majority of which (90%) are caused by human activity [4].

Forest survey of India (FSI) [5] reported maximum forest fires in India occur in tropical dry deciduous forests, which have been increased in last decades [1]. High intensity crown fires consume wild lives. Dead canopy fuels and combustion of all foliage and meristems in a tree crown can cause immediate mortality, unless the tree is able to re-sprout from heat resistant organs [6] as ligni-tubers of Sal. Low to moderate intensity fires often do not constitute a direct lethal threat to mature trees, but rather, may cause a variety of injuries that can subsequently interact to impact whole tree functioning. Fire effects on trees can be classified as two types- first order effects comprise the immediate impacts of heat transfer on plant tissues, Nonlethal first order heat, injuries can trigger second order effects, such as physiological limitations in carbon and water relations or increased susceptibility to insect attacks and pathogenic infections [7]. Fire frequency is similarly responsible to reduce the plant and wildlife diversity. Frequent fires destroy the saplings and hampers seedling establishment [8]. The vast forest in this soil type and zone takes a major role to lower the temperature in summer, maintain local microclimate and underground water level [9,10], beside production of timber and non-timber produces. Microbes including arbuscular mycorrhizae take major role in decomposition and nutrient cycling in forest [11,12], specially, in nutrient poor dry lateritic soil. Fungi belonging to Glomeromycota, form obligate (AM) symbiosis with plants and important driving force of any plant community [13]. The symbiosis enhancing uptake of P and other less mobile nutrients [14], increases the photosynthesis rate and growth. AMF cope up with abiotic stresses, as temperature [15], and drought [16]; and biotic stress of pathogen attack [17]. Burning in forest floor may hamper the symbiotic relation too, affecting sporulation. Spores act as potential inoculum.

Though report on fire effect, are plenty in temperate gymnosperm forests with ectomycorrhizae, report on deciduous forest in dry lands is scanty, in both India and world, as in eastern part of North America [18], in semi-arid woodlands in Mudumalai Tiger Reserve [19]. In northern part of India, temperate forests, some works are done [8] on burning impact on plant community. In burning prone dry deciduous forest and in sal forests in lateritic belt investigation is very much needed as plant regeneration, forest productivity and community development is naturally slow here. No such work is done in dry deciduous Sal or mixed Sal-forest in lateritic belt. Though Arévalo et al. [20] considered prescribed fire is better than cutting in forest regeneration, long-term repeated burning may affect on soil fungal communities. Specially, effect on arbuscular mycorrhizae is largely unknown in comparison to ectomycorrhiza. The main objective of this investigation is to understand the role of fire in forest ecosystem with emphasis on impact of frequency of fire on plant community composition and diversity including impact on AMF sporulation.

# 2. Materials and Methods

## 2.1 Study site

Survey and Sampling was done in Godapiyasal forest (22.4856° N and 87.3208° E) in West Midnapore district of W.B. India, in fourth week of June, 2022. The forest is Sal dominated mixed dry deciduous forest. This area shows four distinct seasons – winter, spring, summer and monsoon in the year. The last ten years data of climate from Midnapore College Climate Centre showed average rainfall is 1484.0 mm occurring mainly in monsoon of mid-June to August. The temperature ranges from 28˚C to 45˚C in the summer and 08˚C to 24˚C in the winter months. Soil is red lateritic, rich in iron and aluminium content and poor in available nutrients. The Natural unburned zone is located one km apart from first time burned zone divided by a highway. The first time burned zone is a coppice forest. The regularly burned zone is two km away from the later.

### 2.2 Sampling

Sampling was done in three sites of the forest. 1. never burned normal stand, 2. first time burned coppice forest and 3. regularly burned forest. Survey and sampling were done randomly within 2 $km^2$ for each site and six quadrates of $10m^2$ were placed for study of vegetation in each site. Plants in each quadrate were listed and identified, the number of individuals of each species was counted and girth at breast height (GBH) at 1.3 m height from soil of trees and basal area of lower life forms were measured. The data we collected used to calculate the density, frequency, abundance, relative frequency, relative density, relative dominance, IVI, diversity indices and similarity index. The Shannon-Weiner diversity Index, Species Richness Indices, Evenness Index, Dominance Index were calculated according to these following formulas:

Shannon -Weiner index diversity:

$$H= -\sum pi \log pi \quad (1)$$

Where $p_i$ = proportion of individuals of species.

Source: [21].

Dominance index/ Simpson Index:

$$D= \sum (ni/N)^2 \quad (2)$$

Source: [22].

Where $n_i$, is the number of individuals in species *i,* N = total number of individuals of all species, and $n_i$/ N = $p_i$ (proportion of individuals of species i), and *S* = species richness.

The evenness of a community can be represented by Pielou's evenness index

$$J=H/Hmax. \quad (3)$$

Source: [23].

***J*** and ***D*** can be used as measures of **species dominance** (the opposite of diversity) in a community. Low J indicates that 1 or few species dominate the community.

Similarity index: Sørenson [24] developed a similarity index that is frequently referred to as the coefficient of community (CC):

$$CC = 2c / (a + b + 2c) \quad (4)$$

*c* is the number of shared species between the two sites and *a* and *b* are the number of species unique to each site.

Soil sampling was done from rhizosphere of different plants in each qudrate from upto 15 cm soil depth. Soil samples of each site was mixed well and divided in three parts for evaluation. Soil sample of 100g was taken in three replicates from each site to study for mycorrhizal spore by water decanting method [25] . Spores were counted under stereo microscope under x60.

## 3. Results

The analysis showed that the normal forest is dominated by *Shorea robusta.* The sub dominant*, Litsea glutinosa* showed relative frequency and relative density much lesser. Though the species, *Diospyros melanoxylon* and *Cleistanthus collinus* are similarly frequent as the dominant, relative density is much lesser and relative dominance is severely poor (**Table 1**). IVI of *Premna latifolia* is next to these two species. Total ten tree species were noticed in unburned forest.

The first time burned site is dominated by *Diospyros melalnoxylon,* with maximum abundance, relative density, relative frequency relative dominance and IVI (**Table 2**). Sal is similarly frequent, but being coppice, with lesser dominance and density than normal site and *D. melalnoxylon. Litsea glutinosa* is another subdominant with the relative density and IVI is next to *Diospyros melalnoxylon.* Other subdominants are *Madhuca longifolia, Combretum chinense* and *Pterocarpus marsupium* respectively.

**Table 1.** Plant Community in Normal unburned Forest.

| Sr no | Name of plant species | Relative frequency | Relative density | Relative dominance | IVI |
|---|---|---|---|---|---|
| 1 | *Shorea robusta* Roxb. | 15.625 | 53.380 | 97.304 | 166.299 |
| 2 | *Diospyros melanoxylon* Roxb. | 15.625 | 18.920 | 0.595 | 35.130 |
| 3 | *Aglaia odoratissima* Bl | 9.375 | 2.700 | 0.097 | 12.171 |
| 4 | *Litsea glutinosa* (Lour).C.B.Rob | 9.375 | 2.700 | 1.655 | 13.730 |
| 5 | *Allophyllus cobbe* L. | 6.250 | 1.350 | 0.142 | 7.743 |
| 6 | *Buchanania* cochinchinensis (Lour)M.R Almeida | 3.125 | 0.680 | 0.012 | 3.807 |
| 7 | *Pterocarpus marsupiun* Roxb. | 6.250 | 1.350 | 0.073 | 7.673 |
| 8 | *Premna latifolia* Roxb. | 12.500 | 4.050 | 0.062 | 16.612 |
| 9 | *Scheichera oleosea (*Lour.)Oken | 6.250 | 1.350 | 0.054 | 7.655 |
| 10 | *Cleistanthus collinus* (Roxb). Benth.ex Hook.f | 15.625 | 13.51 | 0.004 | 29.139 |
| | | 100 | 100 | 99.998 | 299.998 |

**Table 2.** Plant Community in first time burned forest Site.

| Sr no | Name of plant species | Abundance | Relative frequency | Relative density | Relative dominance | IVI |
|---|---|---|---|---|---|---|
| 1 | *Shorea robusta* Roxb. | 5.40 | 9.091 | 13.043 | 13.439 | 35.573 |
| 2 | *Aegle marmelos* (L.) corr. | 1.00 | 5.455 | 1.449 | 0.099 | 7.003 |
| 3 | *Terminalia arjuna* Bed. | 1.66 | 5.455 | 2.415 | 1.232 | 9.102 |
| 4 | *Syzygium cumini* L. | 1.00 | 5.455 | 1.449 | 0.548 | 7.452 |
| 5 | *Combretum chinense* Roxb. | 5.75 | 7.273 | 11.111 | 0.704 | 19.088 |
| 6 | *Diospyros melalnoxylon* Roxb. | 12.6 | 9.091 | 30.434 | 60.938 | 100.463 |
| 7 | *Litsea glutinosa* Lour. | 8.20 | 9.091 | 19.807 | 9.292 | 38.190 |
| 8 | *Madhuca longifolia* (J.Konig.) J.F.Macbr | 2.60 | 9.091 | 6.280 | 8.392 | 23.763 |
| 9 | *Pterocarpus marsupium* Roxb. | 1.60 | 9.091 | 3.865 | 2.504 | 15.460 |
| 10 | *Tectona grandis L.*f | 1.50 | 3.636 | 1.449 | 0.548 | 5.633 |
| 11 | Holarrhena antidysenterica Wall. | 1.33 | 5.455 | 1.932 | 1.780 | 9.167 |
| 12 | Melia azadirachta L. | 1.00 | 3.636 | 0.966 | 0.215 | 4.817 |
| 13 | Schleichera oleosa Lour. | 1.00 | 3.636 | 0.966 | 0.196 | 4.798 |
| 14 | Bridelia retusa L. | 1.00 | 5.455 | 1.449 | 0.004 | 6.908 |
| 15 | Clestanthus collinus Roxb. | 1.00 | 5.455 | 1.449 | 0.049 | 6.953 |
| 16 | Aglaia odoratissima Bl. | 2.00 | 3.636 | 1.932 | 0.059 | 5.627 |
| | | | 100.002 | 99.996 | 99.999 | 299.997 |

In regular burned forest site, Sal, *Shorea robusta* is the most dominant species with maximum abundance, relative density, dominance and IVI (**Table 3**). *Diospyros melanoxylon* is the next abundant and dense tree species with similar relative frequency and high IVI. Other than *Madhuca latifolia* and *Holarrhena antidysenterica*, all tree species were in a sprouting stage from burned ruminating parts with very poor abundance, relative density, relative frequency, relative dominance and IVI. The spiny short trees and shrubs, as *Ziziphus mauritiana, Phoenix acaulis, Streblus asper, Flacourtia indica*, *Meyna laxiflora* seems to somehow fire resistant. *Combretum decandrum* is found both resistant and resilient to fire. The old and hard lianas are fairly resistant to fire, while young lianas are totally destroyed, but showed an induced quick growth after fire. Four undershrub or herbaceous plants, *Eupatorium odoratum, Tephrosia purpurea, Blumea lacera* and *Hemidesmus indicus* are very abundant and frequent with also high density and IVI. These species are more abundant in forest peripheral zone. These species are totally absent in other sites. Annual herb and undershrub vegetation in forest floor was nil in first time burned and scanty in natural unburned forest sites.

**Table 3.** Plant Community in regularly and severely burned forest site.

| Sr no | Name of plant species | Abundance | Relative frequency | Relative density | Relative dominance | IVI |
|---|---|---|---|---|---|---|
| 1 | *Shorea robusta* Roxb. | 18.60 | 6.67 | 29.34 | 83.615 | 119.625 |
| 2 | *Meyna laxiflora* Robyns. | 3.20 | 5.33 | 4.10 | 0.018 | 9.448 |
| 3 | *Ziziphus mauritiana* Lam. | 3.80 | 6.67 | 5.99 | 0.191 | 12.851 |
| 4 | *Flacourtia indica* (Burm.f.) Merr | 3.80 | 6.67 | 5.99 | 0.031 | 12.691 |
| 5 | *Streblus asper* Lour. | 1.33 | 4.00 | 1.26 | 0.077 | 5.337 |
| 6 | *Madhuca latifolia* Roxb. | 1.50 | 5.33 | 1.89 | 0.173 | 7.393 |
| 7 | *Holarrhena antidysenterica* Wall. | 3.00 | 5.33 | 3.79 | 0.942 | 10.062 |
| 8 | *Diospyros melanoxylon* Roxb. | 4.80 | 6.67 | 7.57 | 0.028 | 14.268 |
| 9 | *Carrissa spinarum L.* | 1.50 | 2.67 | 0.95 | 0.030 | 3.65 |
| 10 | *Combretum decandrum* Roxb. | 1.50 | 5.33 | 1.89 | 0.030 | 7.25 |
| 11 | *Phoenix acaulis* Roxb. | 4.50 | 5.33 | 5.68 | 1.560 | 12.57 |
| 12 | *Syzygium cumini* L. | 1.50 | 2.67 | 0.95 | 0.019 | 3.639 |
| 13 | *Manilkara elengi L.* | 1.00 | 4.00 | 0.95 | 0.015 | 4.965 |
| 14 | *Aglaia odoratissima* Bl. | 1.00 | 4.00 | 0.95 | 0.024 | 4.974 |
| 15 | *Gardenia gummifera* L.f | 1.00 | 4.00 | 0.95 | 0.051 | 5.001 |
| 16 | *Cleistanthus collinus* Roxb. | 1.40 | 6.67 | 2.21 | 0.059 | 8.939 |
| *17* | *Limmonia acidissima* L. | 1.33 | 4.00 | 1.26 | 0.019 | 5.279 |
| *18* | *Tephrosia purpurea (L)* Pers | 3.00 | 1.33 | 0.95 | 0.024 | 2.304 |
| *19* | *Eupatorium odoratum* L. | 5.33 | 4.00 | 5.04 | 0.031 | 9.071 |
| *20* | *Blumea lacera* (Burm.f.) DC | 12.66 | 4.00 | 11.99 | 10.867 | 26.857 |
| *21* | *Hemidesmus indicus* (L.) R.Br | 15.0 | 1.33 | 4.73 | 1.926 | 7.986 |
| *22* | *Manilkara hexandra* (Roxb) Dubard | 1.66 | 4.00 | 1.58 | 0.271 | 5.851 |
| | | | 100.00 | 100.00 | 100.001 | 300.001 |

Among the three sites, abundance and density of the four common species varied much (**Figure 1**,**2**). *S. robusta* showed maximum in severely burned, then in normal forest. *D. melalnoxylon* showed maximum in 1st time burned than normal and was decreased in severely burned site. Similar trend was noticed in *A. odorotissima,* in 1st burned site density is very high. But in *C. collinus*, both were maximum in normal followed by in severely burned.

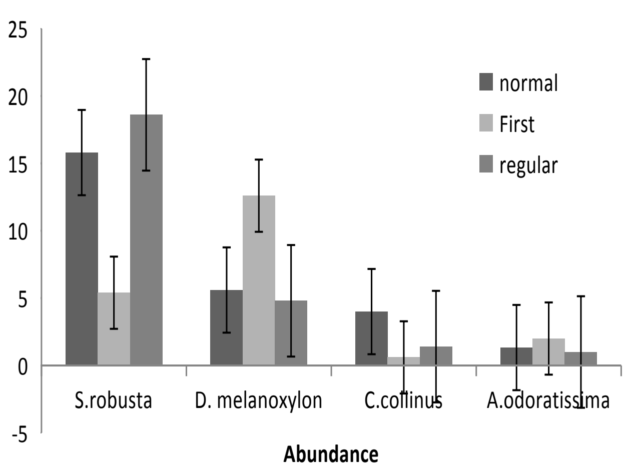


**Figure 1.** Abundance of common species in three sites.

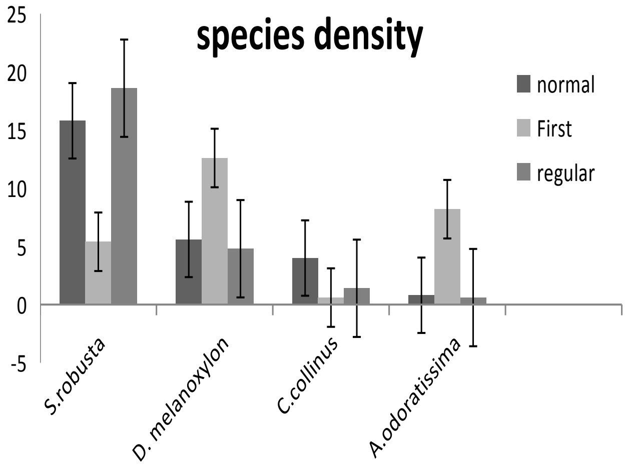


**Figure 2.** Species density of common species in three sites.

Within the two burned site, higher abundance and density was noticed in *C. decandrum* and *M. laxiflora* in first time burned site; while in severely burned site these were maximum in *H. antidysenterica* (**Figure 3**, **4**). Density of *S. cumini* is same in two regions (**Figure 4**). Relative frequency, relative density, relative dominance and IVI of *S. robusta* were maximum in normal forest; relative frequency, and relative density were almost two times more than severely burned forest site (**Figure 5**). The dominant species of coppice forest*, D. melanoxylon* showed maximum relative density, relative dominance and IVI in this forest, while relative dominance of the tree was negligible in other sites; but maximum relative frequency was observed in normal forest and almost two times more than the severely burned forest site (**Figure 6**).

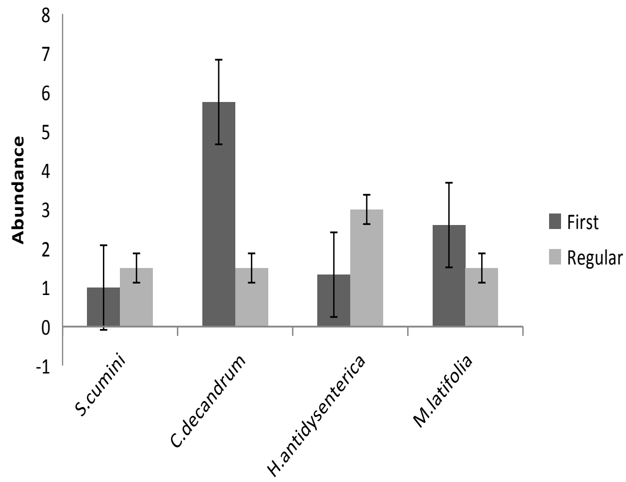


**Figure 3.** Abundance of common species in first time burned coppice forest and regular burned stand.

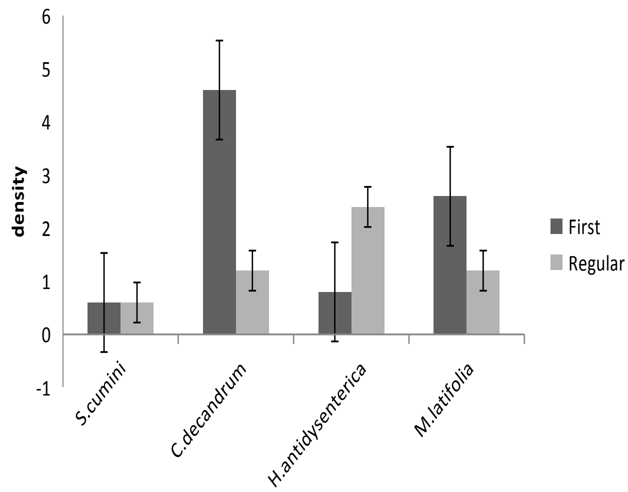


**Figure 4.** Species density of common species in time burned coppice forest and regular burned stand.

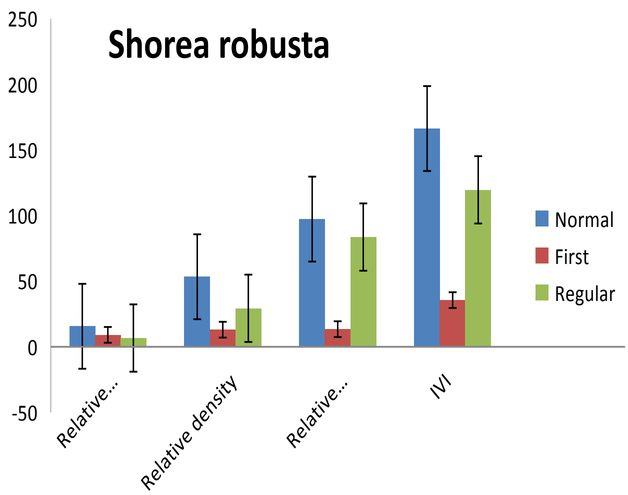


**Figure 5.** Relative frequency, relative density, relative dominance and IVI of *Shorea robusta* in three sites.

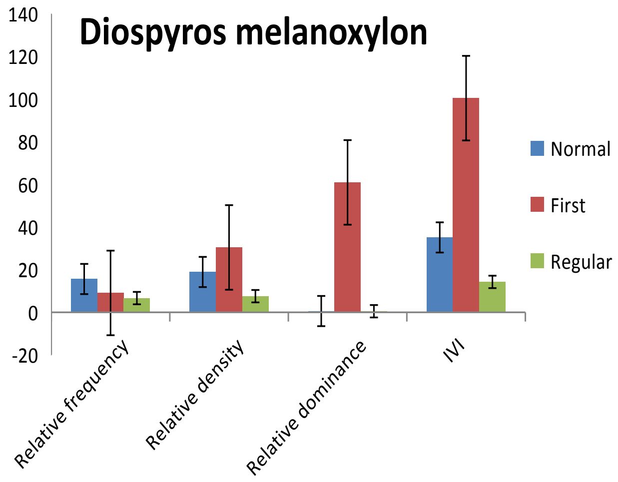


**Figure 6.** Relative frequency, relative density, relative dominance and IVI of *Diospyros melanoxylon* in three sites.

The maximum similarity was noticed within Normal and 1st time burned forest followed by within the two burned forest (**Table 4**). The regularly burned site showed highest value of Evenness, Shannon and Simpson's index indicating high even distribution, then moderate in first time burned and lowest in normal forest (**Table 5**).

**Table 4.** Similarity index and dissimilarity index within different communities**.**

| SITES | Similarity index | Dissimilarity index |
|---|---|---|
| normal and first time burned | 0.222 | 0.778 |
| first time burned and severely burned | 0.153 | 0.847 |
| normal and severely burned | 0.187 | 0.813 |

**Table 5.** Diversity and dominance indices of different communities.

| SITES | Shimpson index | Shannon index | Evenness index |
|---|---|---|---|
| NORMAL | 0.338 | 1.453 | 0.386 |
| 1 YEAR BURNED | 0.837 | 2.164 | 0.956 |
| SEVERELY BURNED | 0.875 | 4.699 | 1.0 |

In normal sites larger spore populations are lesser than small sized spore categories, variations among the spore density of 180-300, 90-180 and > 53 µm sized spores are negligible. AMF spore density of larger sized spores (180 to 300 µm) was noticed severely affected by both frequency of and intensity of fire. 90 -180 µm spores were also reduced to half by fir and regular fire reduced more. Small sized spores are though very less affected or resilient to return and somehow induced by the low intensity fire (**Figure 7**).

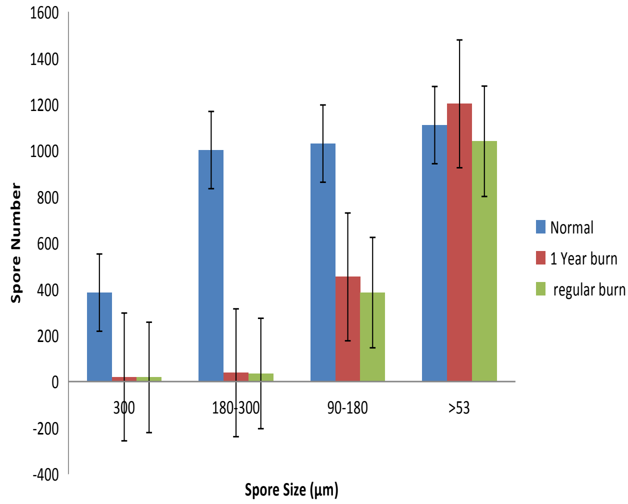


**Figure7.** AMF spore of different sizes) density in 100g soil sample.

## 4. Disccussion

The forest fire is distinctly noticed to shape the plant community. The impact of regular fire is more intense, only the resistant and resilient trees are in good form. Fire modified the species composition and community structure. Regular burning led the loss of sapling growth to a stunted stage and so showed more even distribution of species. Most the dominant and subdominants in deciduous forests have moderate to thick bark and high coppicing ability [26], yet being recurrently affected in sapling stage the most subdominants failed to grow further. Verma and Jayakumar [27] also found that low frequency of fires, though not affected trees, frequent fires affected regeneration. Fourrier et al. [28] also found understorey vegetation of forest floor greatly hampered in a boreal forest. Kittur et al. [29] also found shrub density was high in frequent fire area than normal or low frequent forest. The forest productivity is also hampered, which led to spatio-temporal changes in forest regeneration [30]. The loss of the subdominants and fail to return in community is surely detrimental for the forest ecology and economy too [31]. The forest ethnic community is also depended on forest for livelihood, firewood and medicine. The steady supply is being affected. Forest fire causes devastating loss and irreparable damage to the environment and atmosphere Fail of a large portion of carbon sequestration through the abundant release of $CO_2$ [32] every year would affect the global ecosystem health. This will add to global warming [33] and feed back to climate change. In frequent fires may have some positive role, leading ecosystem functioning, but regular burning along with other anthropogenic interferences lead to forest degradation and fragmentation [34], that undermine the sensitivity of forests to fire [35]. Species composition was observed altered from natural site and invasive weeds population was maximum in regularly and severely burned site. Fire acts as a selection agent of invasive annuals and perennials and favours their establishment [36].

Thugh availability of some nutrients is increased following after fire, but other soil physicochemical conditions deteriorate. Fire affects the soil properties, including soil biological properties, affecting fine roots and beneficial microbes and make the soil water repellent (Weninger et al. [37]. The changed soil characteristics [38] and root damage severely affect AM species diversity and function. Effect of fire on AMF propagule density was observed severely detrimental as much poorer than normal site, though different results are found in other forests. Xiang et al [39] noticed AMF communities are low resistant and high resilient in Chaco forest. Moura et al. [40] also found high resilience and no diversity loss and same propagule density with normal zone after megafire in Brazil. After nine months of fire incidents, the AMF flora was failed to revive, as evidenced from our results in large-spored fungi, which mainly act in soil stabilisation [41] surely hamper soil sustainability and function of nutrient supply.

## Conclusion

The current research focused on comparative impact of long-term forest fire and occasional incidence in dry deciduous forest in India. Though in occasional burned site showed less affected plant community, larger spore forming mycorrhizal fungi were similarly affected in both burned sites and not revived after nine months. Severely burned site failed to regenerate with saplings and burdened with invasive species and thorny shrubs. Only fire hardy tree species survives. Fire selected the community structure in burned sites. Though evenness increases with burning, similarity is maximum within the normal and first time burned forest. Burning hampers the soil quality and microflora hampering productivity and carbon sequestration. As most of the fires are man -made mass awareness of the loss in large-scale is needed to prevent. Detail study of mycorrhizal and edaphic relation to be studied.

## Author Contributions

Concept and writing SG, field work: SG, M.K, SB, SD. calculations Table, SD, M.K. Lab work: SB.

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