Effect of Burning Intensity on Soil Seed Bank in Clay and Sandy Soils in North Kordofan State, Sudan

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Abstract: Tow experiments were conducted in Northern Kordofan State during the seasons 2004/2005 and 2005/2006 to investigate the effect of burning and its intensity on soil seed bank in clay and sandy soils. One of the experiments was conducted to investigate the amount of live seeds in the soil (seed bank) in burned and unburned sites in clay and sandy soils. The other experiment was conducted to investigate the impact of fire intensity on live soil seed bank and plant species by using the treatments; no burning as a control, burning with the existing fuel, burning with double existing fuel and burning with triple existing fuel. Completely randomized design with twenty replicates was used. The results of the first experiment showed that the number of live seeds in the soil seed bank was higher in unburned site compared to the burned site. Soil seed bank was significantly higher in clay soil than in sandy soil in both experiments. In the second experiment, the number of live seeds in soil decreased with the increase in burning intensity. Live seeds were higher in the top-soil compared to sub-soil in the two experiments. The plants, *Dactyloctenum aegyptium* and *Ipomea cordofana* were not affected by intensity of burning in clay soil. In sandy soil, the densities of *Dactyloctenum aegyptium* and *Cenchrus ciliars* decreased with the increase in fire intensity. The densities *of Fimbristylis hispidula* and *Eragrostis tremula* increased with the increase in fire intensity in sandy soil. The effect of fire intensity on the density of other species was not consistent, but they ware all reduced at higher intensity.

Keywords: Fire, Fuel load, Fire intensity, Seed number.

Introduction

In many rangelands all over the world, fire has been used as a management tool of range vegetation in various ways; to reduce bush cover, influence changes in species composition, improve the quality of forage to animals and to reduce disease-causing pests (Okello *et al*., 2007). Fire influences changes in vegetation on its own and in conjunction with other factors like herbivory, climate, and soils (Whelan, 1995).

Disturbance by fire can cause mortality of aerial or soil-stored seed, but it can also stimulate germination (Stephan *et al*., 2010). Direct impact of fire on soil seed bank occurs either by destroying non-dormant seeds or by breaking the seed coat of dormant seeds. The combined effects of these two processes will determine germination response from seed banks (Stephan, *et al.,* 2010). The resilience of rangelands after disturbance by fire or any other factors depends on the presence of viable seeds of plant species in the soil seed bank. The soil seed bank usually consists of viable, ungerminated seeds that are stored in the soil (Bigwood and Inouye, 1988). These seeds enter the soil as they are produced by local plants and fall to the ground, or dispersed into the area and resilience (Harper, 1977 and Elsafori *et al*., 2011). Soil seed banks are considered as important components of vegetation dynamics affectting both ecosystem resistances. In order for the natural vegetation to return, a viable seed bank would have to exist in the soil. Seed depths in the soil and temperature affect soil seed bank responses to fire (Carrington, 2010). Soil type perse did not influence seed longevity, but variation in water content and temperature between soils due to differences in physical and chemical properties resulted in a significant effect on seed persistence and seedling vigor (Long *et al*., 2009).

In different parts of Sudan, uncontrolled burning is a serious threat to rangelands resulting in the consumption of 10-30% of the standing dry forage, so annually a network of fire-breaks of more than 35000 km are established to check the spread of these fires and protect dry grass (Zaroug, 2006). This annual burning in the short term deprived pastoralists of fodder and in the longer term cause degradation to rangeland by favoring tree and grass species unpalatable to livestock (Trigg *et al*., 2011). Since burning occurrence, naturally or intentionally, in semi-arid and savanna rangelands in Sudan is inevitable, its impact on vegetation need to be investigated. The extent to which burning impacted the vegetation and soil seed bank depends on fire regimes, i.e., intensity and frequency. The objectives of the study were to study and to assess the impacts of burning and its intensity on the live seed bank and plant species in the seed bank in clay and sandy soils in Northern Kordofan state.

Materials and Methods

Site description

The study was conducted in Northern Kordofan State during the seasons 2004/2005 and 2005/2006 to study the effect of burning on soil seed bank. The area lies between latitudes 12º 00 and 16º 10" N, longitudes 26º 15" and 30º 30" E, with mean elevation of about 750 meters above sea level. The topography is characterized by being flat with small seasonal water courses. The climate of the area is semi-arid with low erratic rainfall ranging between 300-350 mm per annum. The mean maximum temperature of the hottest month (May) is 35˚C and 40˚C and the coolest month (January) is 18˚C. Relative humidity is 80% in August and 20% in March-May. The soil in the area varies from sandy, sandy clay and clay soils. The vegetation in the area consists of 81.6% annual grasses, 14.7% annual forbs, 2.8 perennial grasses and 0.9% shrubs. The most dominant plants, that constitute 74% of the total, were Banu (*Eragrostis tremula*) and Haskaneit (*Cenchrus biflorus*). (Range Management Department Annual Reports, 2006)

Experiments:

Two experiments were conducted to investigate the impact of burning on plant species and soil seed bank on sandy and clay soils. In the first experiment, four sites were selected:

1- Burned in clay soil (fire frequency was three years).
2- Unburned in clay soil.
3- Burned in sandy soil (fire frequency was three years).
4- Unburned in sandy soil.

From each site ten soil samples of 10 × 10 × 10 cm were taken at random, as replicates for each treatment. The samples were put in polythene bags and subject to germination. The number of germinated seeds was counted to determine the number of live seeds per 100 cm^2.

The second experiment was conducted at 2005 and 2006 season. At the end of the rainy season, two sites were chosen, one on sandy soil, at Setia area, and the other on clay soil, at Alnuala (Hilat Abaker) area. On each site, four 20x20 m paddocks were assigned. The paddocks in each site were initially similar. One paddock was left out without burning as a control, one burned with the existing amount of fuel, F1 (450kg/ha for sandy soil, and 1400 kg/ha^2 for clay soil), another one burned with double the same amount of existing fuel designated as F2 and the last one burned with triple the existing fuel designated as F3. After burning, 10 soil samples (10x10 cm) were taken from topsoil (0-10 cm) and subsoil (10–20cm.) from each paddock as replicates for treatments. The samples were put in polythene bags for germination to determine live seed by species in the soil (seed bank). After two months, the established plant seedlings were identified and counted by species to determine the number of plant species per square meter. The data obtained in this study was subjected to analysis of variance (ANOVA) as a completely randomized design replicated 10 times for the two experiments. Least significant difference (LSD) was used for mean separation for both experiments (Gomez and Gomez, 1984).

Results

The effect of burning and soil type on soil seed bank was shown in Table1. The number of seeds per 100 cm^2 was significantly higher in unburned site than in burned site. Soil seed bank was significantly higher in clay soil than in sandy soil (Fig. 1).

Table 2 shows the effect of burning with different fire intensities on soil seed bank in different soil depths in clay and sandy soil. Number of germinated seeds in soil decreased with the increase in fire intensity. A higher number of seeds were found in the control, while a lower number was found in sites burned under more fuel (F3). In both soils, the number of live seeds was higher in topsoil than in subsoil (Fig. 2).

Fuel load (fire intensity) and soil depth interaction for seed bank in clay and sandy soil was shown in Table (3). The unburned plots and the plots burned with the existing fuel in topsoil showed significantly (0.05) higher number of seeds than other fuel treatments in both soil depths. The lowest number of seeds was observed at higher intensity in both soils.

The effect of burning at different intensities on density of lives seeds of different species in the seed bank in clay soil is shown in Table 4. The species present in higher density were *Dactyloctenum aegyptium* and *Ipomea cordofana. Chloris gayana* and *Echinochloa clonum* were present in relatively low density. Other species, such as *Ocimum basilicum, Chorchorus olitorious* and *Tepharosia virginiana* were present with very low density. *Dactyloctenum aegyptium* was not affected by fire up to double fuel load and then drop to 1.5 seedlings per 100 cm^2 when burning at triple load fuel treatment in clay soil. *Ipomea cordofana* was not affected by fuel load burning up to double sampling, but significantly increased in triple load compared to control and burning with the existing fuel in clay soil. The densities of seedling of some species such as *Echinochloa clonum*, *Chorchorus olitorious* and *Tepharosia virginiana* were significantly reduced when burned under double and triple fuel load.

The effect of burning at different fuel loads on density of different species with emerging seedlings from the seed bank in sandy soil was shown in Table 5. The species present in higher density were *Fimbristylis hispidula and Cenchrus ciliars. Dactyloctenum aegyptium, Solanum incanum, Eragrostis tremula and Echinochloa clonum* were present in relatively low density, while the densities of other species such as *Bergia suffruticosa* and *Sesamun alatum* were very low. The densities of *Dactyloctenum aegyptium* and *Cenchrus ciliars* decreased with the increase in fire intensity, while the densities of *Fimbristylis hispidula* and *Eragrostis tremula* increased with the increase of fire intensity. The effect of fire intensity on the density of *Echinochloa clonum, Solanum incanum*, *Bergia suffruticosa* and *Sesamun alatum* was not consistent, but they are all reduced when burned with triple fuel.

Table 1. The effect of burning and soil type on number of live seed in the soil seed bank

Treatments	First year	Second year
	Burning	
Unburned	18.0a	23.0 a
Burned	14.3b	19.7 b
LSD	2.6	2.6
	Soil type	
Clay	23.8 a	29.8 a
Sandy	8.5 b	12.9 b
LSD	2.6	2.6
CV (%)	25.4	18.7

Means with the same letter(s) within column for each treatment are not significantly different using Least Significant Difference (LSD) at 0.05 probability level.

Table 2. The effect of burning at different fuel load on number of live seed in the soil seed bank (seeds per 100 cm^2) at different soil depths in clay and sandy soils

Treatments	Clay	Sandy
	Fuel load	
Control	24.60 a	9.50 a
F1	22.00 a	8.13 ab
F2	10.75 b	5.75 b
F3	4.88 c	1.50 c
LSD	5.69	3.60
	Soil depth	
Top soil	21.13 a	10.00 a
Sub-soil	10.00 b	2.44 b
LSD	2.6	2.6
CV (%)	25.4	25.4

Means with the same letter(s) within column for each treatment are not significantly different using Least Significant Difference at 0.05 probability level
Control = No burning, F1 = Burning with the existing fuel, F2 = Burning with double the existing fuel, F3 = Burning with triple the existing fuel

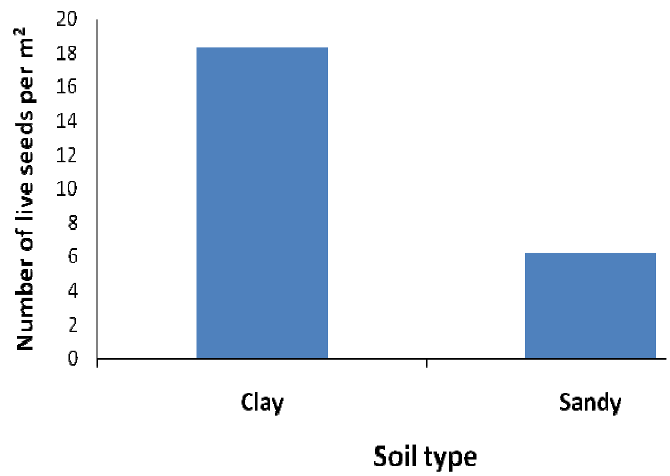

Fig.1: Effect of fire on number of live seed in sandy and clay soil

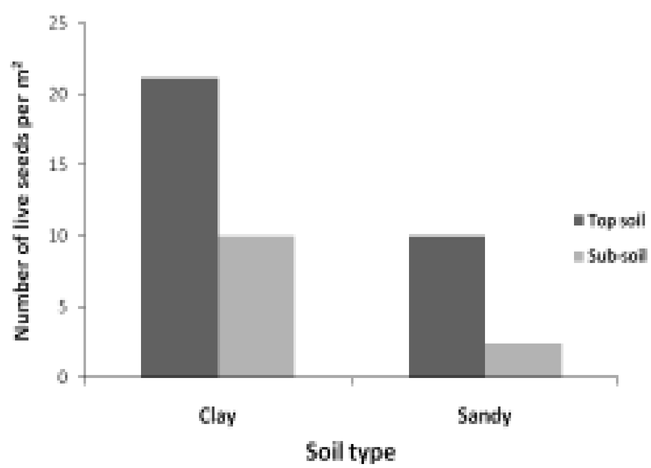

Fig.1: Effect of fire on number of live seed in sandy and clay soil

Table 3. Fuel load and soil depth interaction for live seed number in the soil seed bank.

	Fuel load treatments			
	Control	F1	F2	F3
Clay Soil depth				
Top-soil	35.50 a	30.75 ab	13.75 b	4.50 c
Sub-soil	13.25 c	13.25 c	7.50 bc	5.25 c
Sandy soil depth				
Top-soil	16.25 a	13.75 a	8.75 b	1.25 c
Sub-soil	2.75c	2.50 c	2.75 c	1.75 c

Table 4. Effect of burning at different fuel load on density (plants per 100cm^2) of different plant species on clay soil

Treatments	Plant species							
	DaAe	EcCo	ChGa	IpCo	ErTr	OcBa	CoOl	TeVi
Control	15.9 a	3.5 b	4.1 b	8.8 b	6.5 bc	1.1 ab	1.6 ab	1.7 a
F1	14.1 a	6.7 a	7.1 a	8.7 b	10.7 a	2.2 a	3.2 a	1.1 ab
F2	14.0 a	2.8 b	2.5 b	9.8 ab	7.9 ab	0.7 b	1.3 b	0.1 b
F3	1.5 b	1.2 b	1.9 b	14.4 a	3.0 c	1.3 ab	1.3 b	0.5 b
LSD	5.19	3.06	3.01	5.38	3.63	1.31	1.66	1.11

Means with the same letter(s) within column are not significantly different at 0.05 probability level
DaAe = *Dactyloctenium aegyptium*, EcCo = *Echinocloa colonum*, ChGa = *Chloris gayana*, IpCo = *Ipomea cordofana*, ErTr = *Eragrostis tremula*, OcBa = *Ocimum basilicum*, CoOl = *Corchorus olitorious*, TeVi = *Tephrosia virginiana*

Table 5. Effect of burning at different fuel load on density (plants per square meter) of different plant species on sandy soil

Treatments	Plant species							
	DaAe	EcCo	FiHi	ErTr	SoIn	CeCi	BeSu	SeAl
Control	9.2 a	0.8 c	9.2 c	2.5 c	7.4 a	11.8 a	1.6 a	2.1 ab
F1	3.5 b	3.3 b	19.2a	6.4 b	4.1 b	10.5 a	0.9 a	2.6 a
F2	3.7 b	5.5 a	12.9 bc	3.3 bc	0.8 b	5.0 b	0.5 a	2.1 ab
F3	0.3 c	0.6 c	35.5 a	12.8 a	7.0 a	0.9 c	1.3 a	0.6 b
LSD	2.05	1.39	7.30	3.44	2.28	3.09	1.25	1.42

Means with the same letter(s) within column are not significantly different at 0.05 probability level

DaAe = *Dactyloctenium aegyptium*, EcCo = *Echinocloa colonum*, ErTr = *Eragrostis tremula*, FiHi = *Fimbristylis hispidula*, SoIn = *Solanum incanum*, CeCi = *Cenchrus ciliaris*, BeSu = *Bergia Suffruticosa*, SeAl = *Sesamum alatum*

Discussion

The reduction in the seed bank under burn may be due to negative effect of fire on seeds of many species, especially those which are not fire-tolerant. Since burning occurs in dry season, higher fire intensity was expected to impact seed bank due to high temperature caused by fire as explained by Turna and Bilgili (2006). This result is in line with Laterra *et al*., (2006) and Martinez- Orea *et al*., (2010) who reported that burning reduces the amount of live seeds on the seed bank. On clay soil the number of seeds was found to be more than in sandy soil because plant density was higher with more seeds. Moreover, clay soils have many cracks that keep more seeds away from fire.

More seeds were found on topsoil than subsoil because very little number of seeds could penetrate down to the subsoil, unless there are cracks or when soil is subjected to tillage operation (Ashrafi, 2006). This result is supported by Hassan (2004) Elsafori, *et al*., (2011) and Tessema *et al*., (2011) who reported that most of the soil seed bank concentrated on the top soil.

The number of germinated seeds decreased as the fuel load increased. This is due to the fact that with the increase in fuel, intensity of fire increased and soil heating increased, especially in dry season. Therefore, high soil temperature reduced live soil seed bank as reported by Turna and Bilgili (2006). Similar results were obtained by Lee (2004), and Esposito *et al*., (2006). They found a decrease in seedling emergence due to high fire intensity.

In clay soil, the live seed banks of *Dactylo-ctenum aegyptium*, *Ipomea cordofana* were not affected by fire intensity up to burning with double load and that of *Eragrostis tremula* remained high even at high fire intensity. This might be due to the fact that those species have high tolerance to fire or their seed dormancy was broken by heat and smoke (Dayamba, 2010) which is clear for *Eragrostis tremula* at higher fire intensity. Other species such as *Chloris gayana, Echinochloa clonum, Chorch-orus olitorious* and *Tepharosia virginiana,* were their response of seed bank to fire intensity not consistent. However, seed bank was lower at higher fire intensity. This inconsistency in response may be due to the fact that those species were not evenly distributed in the experimental area.

persistence of the sedge plant *(Fimbristylis hispidula),* which is well adapted under sandy soils (Scarpe 1986), produced a large number of small hard seeds that stimulated for germination by fire, persist very well under burning conditions. Buffelgrass, *C. ciliaris*, areas where fire is usually occurs. This indicated that this grass species is a fire-tolerant plant. The tolerance to fire by this species had been also reported by Cook *et al*., (2005). However, the densities of live seed for *Dactyloctenum aegyptium* and *Cenhrus ciliars* were negatively affected by high fire intensity while the densities of *Fimbristylis hispidula* and *Eragrostis tremula* positively affected by high fire intensity. The effect of fuel load on the density of *Echinochloa clonum, Solanum incanum*, *Bergia suffruticosa* and *Sesamun alatum* was not consistent, but they were all reduced when burned with triple fuel. The inconsistent response of these species to fire intensity might be due to that these were not abundant and not evenly distributed in the range. The study concluded that high fire intensity decreased the number of live seeds in the seed bank on both clay and sandy soils. The number of germinated seeds in clay soil was more than in sandy soil. Topsoil stored more seeds than subsoil. *Dactyloctenum aegyptium* and *Ipomea cordofana* were less affected by fire intensity in clay soils, while *Fimbristylis hispidula* and *Eragrostis tremula* were positively affected by fire intensity.

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4- Unburned in sandy soil.

From each site ten soil samples of 10 × 10 × 10 cm were taken at random, as replicates for each treatment. The samples were put in polythene bags and subject to germination. The number of germinated seeds was counted to determine the number of live seeds per 100 cm^2.

The second experiment was conducted at 2005 and 2006 season. At the end of the rainy season, two sites were chosen, one on sandy soil, at Setia area, and the other on clay soil, at Alnuala (Hilat Abaker) area. On each site, four 20x20 m paddocks were assigned. The paddocks in each site were initially similar. One paddock was left out without burning as a control, one burned with the existing amount of fuel, F1 (450kg/ha for sandy soil, and 1400 kg/ha^2 for clay soil), another one burned with double the same amount of existing fuel designated as F2 and the last one burned with triple the existing fuel designated as F3. After burning, 10 soil samples (10x10 cm) were taken from topsoil (0-10 cm) and subsoil (10–20cm.) from each paddock as replicates for treatments. The samples were put in polythene bags for germination to determine live seed by species in the soil (seed bank). After two months, the established plant seedlings were identified and counted by species to determine the number of plant species per square meter. The data obtained in this study was subjected to analysis of variance (ANOVA) as a completely randomized design replicated 10 times for the two experiments. Least significant difference (LSD) was used for mean separation for both experiments (Gomez and Gomez, 1984).

Results

The effect of burning and soil type on soil seed bank was shown in Table1. The number of seeds per 100 cm^2 was significantly higher in unburned site than in burned site. Soil seed bank was significantly higher in clay soil than in sandy soil (Fig. 1).

Table 2 shows the effect of burning with different fire intensities on soil seed bank in different soil depths in clay and sandy soil. Number of germinated seeds in soil decreased with the increase in fire intensity. A higher number of seeds were found in the control, while a lower number was found in sites burned under more fuel (F3). In both soils, the number of live seeds was higher in topsoil than in subsoil (Fig. 2).

Fuel load (fire intensity) and soil depth interaction for seed bank in clay and sandy soil was shown in Table (3). The unburned plots and the plots burned with the existing fuel in topsoil showed significantly (0.05) higher number of seeds than other fuel treatments in both soil depths. The lowest number of seeds was observed at higher intensity in both soils.

The effect of burning at different intensities on density of lives seeds of different species in the seed bank in clay soil is shown in Table 4. The species present in higher density were *Dactyloctenum aegyptium* and *Ipomea cordofana. Chloris gayana* and *Echinochloa clonum* were present in relatively low density. Other species, such as *Ocimum basilicum, Chorchorus olitorious* and *Tepharosia virginiana* were present with very low density. *Dactyloctenum aegyptium* was not affected by fire up to double fuel load and then drop to 1.5 seedlings per 100 cm^2 when burning at triple load fuel treatment in clay soil. *Ipomea cordofana* was not affected by fuel load burning up to double sampling, but significantly increased in triple load compared to control and burning with the existing fuel in clay soil. The densities of seedling of some species such as *Echinochloa clonum*, *Chorchorus olitorious* and *Tepharosia virginiana* were significantly reduced when burned under double and triple fuel load.

The effect of burning at different fuel loads on density of different species with emerging seedlings from the seed bank in sandy soil was shown in Table 5. The species present in higher density were *Fimbristylis hispidula and Cenchrus ciliars. Dactyloctenum aegyptium, Solanum incanum, Eragrostis tremula and Echinochloa clonum* were present in relatively low density, while the densities of other species such as *Bergia suffruticosa* and *Sesamun alatum* were very low. The densities of *Dactyloctenum aegyptium* and *Cenchrus ciliars* decreased with the increase in fire intensity, while the densities of *Fimbristylis hispidula* and *Eragrostis tremula* increased with the increase of fire intensity. The effect of fire intensity on the density of *Echinochloa clonum, Solanum incanum*, *Bergia suffruticosa* and *Sesamun alatum* was not consistent, but they are all reduced when burned with triple fuel.

Table 1. The effect of burning and soil type on number of live seed in the soil seed bank

Treatments	First year	Second year
	Burning	
Unburned	18.0a	23.0 a
Burned	14.3b	19.7 b
LSD	2.6	2.6
	Soil type	
Clay	23.8 a	29.8 a
Sandy	8.5 b	12.9 b
LSD	2.6	2.6
CV (%)	25.4	18.7

Means with the same letter(s) within column for each treatment are not significantly different using Least Significant Difference (LSD) at 0.05 probability level.

Table 2. The effect of burning at different fuel load on number of live seed in the soil seed bank (seeds per 100 cm^2) at different soil depths in clay and sandy soils

Treatments	Clay	Sandy
	Fuel load	
Control	24.60 a	9.50 a
F1	22.00 a	8.13 ab
F2	10.75 b	5.75 b
F3	4.88 c	1.50 c
LSD	5.69	3.60
	Soil depth	
Top soil	21.13 a	10.00 a
Sub-soil	10.00 b	2.44 b
LSD	2.6	2.6
CV (%)	25.4	25.4

Means with the same letter(s) within column for each treatment are not significantly different using Least Significant Difference at 0.05 probability level
Control = No burning, F1 = Burning with the existing fuel, F2 = Burning with double the existing fuel, F3 = Burning with triple the existing fuel

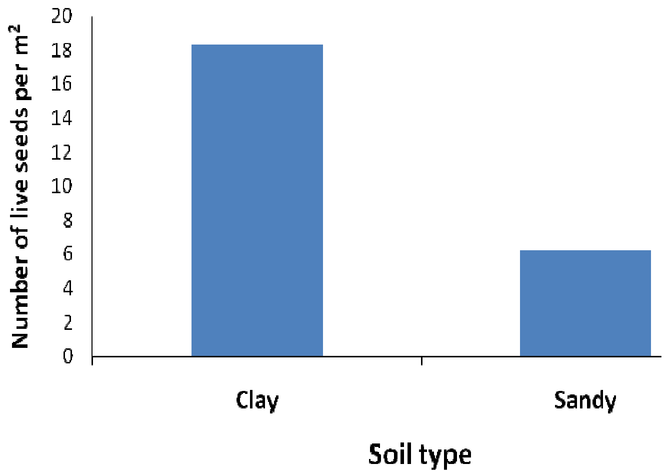

Fig.1: Effect of fire on number of live seed in sandy and clay soil

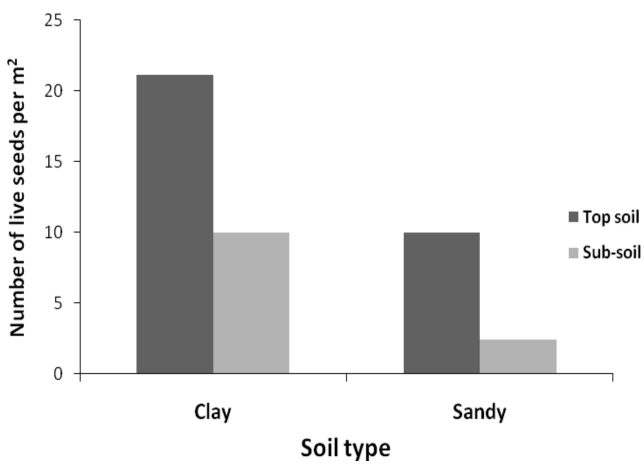

Fig.1: Effect of fire on number of live seed in sandy and clay soil

Table 3. Fuel load and soil depth interaction for live seed number in the soil seed bank.

	Fuel load treatments			
	Control	F1	F2	F3
Clay Soil depth				
Top-soil	35.50 a	30.75 ab	13.75 b	4.50 c
Sub-soil	13.25 c	13.25 c	7.50 bc	5.25 c
Sandy soil depth				
Top-soil	16.25 a	13.75 a	8.75 b	1.25 c
Sub-soil	2.75c	2.50 c	2.75 c	1.75 c

Table 4. Effect of burning at different fuel load on density (plants per 100cm^2) of different plant species on clay soil

Treatments	Plant species							
	DaAe	EcCo	ChGa	IpCo	ErTr	OcBa	CoOl	TeVi
Control	15.9 a	3.5 b	4.1 b	8.8 b	6.5 bc	1.1 ab	1.6 ab	1.7 a
F1	14.1 a	6.7 a	7.1 a	8.7 b	10.7 a	2.2 a	3.2 a	1.1 ab
F2	14.0 a	2.8 b	2.5 b	9.8 ab	7.9 ab	0.7 b	1.3 b	0.1 b
F3	1.5 b	1.2 b	1.9 b	14.4 a	3.0 c	1.3 ab	1.3 b	0.5 b
LSD	5.19	3.06	3.01	5.38	3.63	1.31	1.66	1.11

Means with the same letter(s) within column are not significantly different at 0.05 probability level
DaAe = *Dactyloctenium aegyptium*, EcCo = *Echinocloa colonum*, ChGa = *Chloris gayana*, IpCo = *Ipomea cordofana*, ErTr = *Eragrostis tremula*, OcBa = *Ocimum basilicum*, CoOl = *Corchorus olitorious*, TeVi = *Tephrosia virginiana*

Table 5. Effect of burning at different fuel load on density (plants per square meter) of different plant species on sandy soil

Treatments	Plant species							
	DaAe	EcCo	FiHi	ErTr	SoIn	CeCi	BeSu	SeAl
Control	9.2 a	0.8 c	9.2 c	2.5 c	7.4 a	11.8 a	1.6 a	2.1 ab
F1	3.5 b	3.3 b	19.2a	6.4 b	4.1 b	10.5 a	0.9 a	2.6 a
F2	3.7 b	5.5 a	12.9 bc	3.3 bc	0.8 b	5.0 b	0.5 a	2.1 ab
F3	0.3 c	0.6 c	35.5 a	12.8 a	7.0 a	0.9 c	1.3 a	0.6 b
LSD	2.05	1.39	7.30	3.44	2.28	3.09	1.25	1.42

Means with the same letter(s) within column are not significantly different at 0.05 probability level
DaAe = *Dactyloctenium aegyptium*, EcCo = *Echinocloa colonum*, ErTr = *Eragrostis tremula*, FiHi = *Fimbristylis hispidula*, SoIn = *Solanum incanum*, CeCi = *Cenchrus ciliaris*, BeSu = *Bergia Suffruticosa*, SeAl = *Sesamum alatum*

Discussion

The reduction in the seed bank under burn may be due to negative effect of fire on seeds of many species, especially those which are not fire-tolerant. Since burning occurs in dry season, higher fire intensity was expected to impact seed bank due to high temperature caused by fire as explained by Turna and Bilgili (2006). This result is in line with Laterra *et al*., (2006) and Martinez- Orea *et al*., (2010) who reported that burning reduces the amount of live seeds on the seed bank. On clay soil the number of seeds was found to be more than in sandy soil because plant density was higher with more seeds. Moreover, clay soils have many cracks that keep more seeds away from fire.

More seeds were found on topsoil than subsoil because very little number of seeds could penetrate down to the subsoil, unless there are cracks or when soil is subjected to tillage operation (Ashrafi, 2006). This result is supported by Hassan (2004) Elsafori, *et al*., (2011) and Tessema *et al*., (2011) who reported that most of the soil seed bank concentrated on the top soil.

The number of germinated seeds decreased as the fuel load increased. This is due to the fact that with the increase in fuel, intensity of fire increased and soil heating increased, especially in dry season. Therefore, high soil temperature reduced live soil seed bank as reported by Turna and Bilgili (2006). Similar results were obtained by Lee (2004), and Esposito *et al*., (2006). They found a decrease in seedling emergence due to high fire intensity.

In clay soil, the live seed banks of *Dactylo-ctenum aegyptium*, *Ipomea cordofana* were not affected by fire intensity up to burning with double load and that of *Eragrostis tremula* remained high even at high fire intensity. This might be due to the fact that those species have high tolerance to fire or their seed dormancy was broken by heat and smoke (Dayamba, 2010) which is clear for *Eragrostis tremula* at higher fire intensity. Other species such as *Chloris gayana, Echinochloa clonum, Chorch-orus olitorious* and *Tepharosia virginiana,* were their response of seed bank to fire intensity not consistent. However, seed bank was lower at higher fire intensity. This inconsistency in

response may be due to the fact that those species were not evenly distributed in the experimental area.
persistence of the sedge plant *(Fimbristylis hispidula),* which is well adapted under sandy soils (Scarpe 1986), produced a large number of small hard seeds that stimulated for germination by fire, persist very well under burning conditions. Buffelgrass, *C. ciliaris*, areas where fire is usually occurs. This indicated that this grass species is a fire-tolerant plant. The tolerance to fire by this species had been also reported by Cook *et al*., (2005). However, the densities of live seed for *Dactyloctenum aegyptium* and *Cenhrus ciliars* were negatively affected by high fire intensity while the densities of *Fimbristylis hispidula* and *Eragrostis tremula* positively affected by high fire intensity. The effect of fuel load on the density of *Echinochloa clonum, Solanum incanum*, *Bergia suffruticosa* and *Sesamun alatum* was not consistent, but they were all reduced when burned with triple fuel. The inconsistent response of these species to fire intensity might be due to that these were not abundant and not evenly distributed in the range. The study concluded that high fire intensity decreased the number of live seeds in the seed bank on both clay and sandy soils. The number of germinated seeds in clay soil was more than in sandy soil. Topsoil stored more seeds than subsoil. *Dactyloctenum aegyptium* and *Ipomea cordofana* were less affected by fire intensity in clay soils, while *Fimbristylis hispidula* and *Eragrostis tremula* were positively affected by fire intensity.

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تأثير شدة الحريق على بنك البذور الحية فى التربة الطينية الرملية فى ولاية شمال كردفان، السودان

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المستخلص:

أجريت تجربتين في ولاية شمال كردفان في المواسم 2005/2004 و 2006/2005 لدراسة تأثير الحريق وشدته على بنك البذور الحية في التربة الطينية و الرملية. التجربة الأولى أجريت لمعرفة كمية البذور الحية في التربة (بنك البذور الحية) في مواقع تعرضت للحريق و أخرى غير محروقة في التربة الطينية و الرملية. التجربة الثانية أجريت لدراسة تأثير شدة الحريق على مخزون البذور الحية في التربة الطينية و الرملية باستخدام أربع معاملات هي: أرض غير محروقة كشاهد، حرق النباتات الموجودة، حرق النباتات الموجودة بإضافة كمية مساوية لها و حرق النباتات الموجودة بإضافة كمية نباتات تساوى مرتين من النباتات الموجودة. استخدم التصميم العشوائي الكامل بعشرين مكررا. أظهرت النتائج في التجربة الأولى إن عدد البذور الحية في بنك البذور في التربة كان أعلى معنويا في التربة الطينية من الرملية. في التجربة الثانية، عدد البذور الحية في التربة ازداد بزيادة شدة الحريق. عدد البذور الحية كان أعلى في أعلى التربة بالمقارنة مع أسفل التربة في التجربتين. كثافة الأنواع النباتية *Dactyloctenum aegyptium* و *Ipomea cordofanan* لم تتأثر سلبا بالحريق حتى المستوى الثاني من شدة الحريق مع زيادة بالنسبة للنوع *Ipomea cordofanan* و نقص للنوع *Dactyloctenum aegyptium* في المستوى الأعلى لشدة الحريق في التربة الطينية. في التربة الرملية، كثافة النوع *Dactyloctenum aegyptium* و *Cenhrus ciliars* قلت بزيادة شدة الحريق. كثافة الأنواع النباتية، *Fimbristylis hispidula* و *Eragrostis tremula* ازدادت بزيادة شدة الحريق في التربة الرملية. تأثير شدة الحريق على كثافة الأنواع النباتية الأخرى لم يكن منسجما و لكنها قلت عند شدة الحريق في كل أنواع الترب.