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Effect of Fire on the Viability of Seeds of Acacia seyal Buried in the Soil

Research Article

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Abstract

Natural forests of the clay plain of Sudan are continuously decreasing for various reasons including horizontal expansion on cultivation of crops, cutting for fuelwood and grazing. Then, it becomes more important to mobilize the soil seed bank to restore or reforest the vast cleared areas. Therefore, study was carried out to provide some information on the impact of fire burning on the soil seed bank of the dominant tree species in central clay plain of the Sudan, the *Acacia seyal*, which is frequently devastated by fire.

Seeds of *A. seyal* with 89% viability were scattered on the soil surface and buried at depths of 5 cm, 10 cm in plots of 1 m². Each plot was mattresses with dry grass biomass of 0.5, 1.0 and 1.5 kg/m² to generate fire of various intensities and residence time. The seeds were dug subsequent to firing to count the recovered ones and test their viability; the lost and charred seeds were also counted.

The percentage of the recovered seeds in the buried plots (71%) was significantly less than those in unburied ones (79%). However, the differences between the plots of various fire intensities were not significant. The germination of all recovered seeds did not exceed 53%, and this percentage decreased as the fire intensity increased. The viability of the recovered seeds decreased from 89% initially to 55% after burning. The percentage of perished seeds was counted as 5% including both the lost (3%) and the charred seeds (2%).

Introduction

Talih (*Acacia seyal*) is a very important tree species for the versatile uses of its wood, the leaves and flowers as fodder for animals, protects and enriches the soil. It occurs in association with *Balanites aegyptiaca* in the low rainfall woodland with grass on the clay plains of central Sudan, where the rainfall is from 500 to 800 mm.

The average growing stock in natural forests at the age of 50 to 60 years is estimated to 24 m^3 ha^{-1} and the total above ground volume about 33 m^3 ha^{-1} [1]. Abdel Nour and Satie [2], ElSiddig [3] and Vink [4] mentioned that the stocking volume in natural productive stands range between 15 to 45 m^3 ha^{-1} at a felling period of 25 years.

Drought in combination with human activities such as cropping, wood cutting and grazing may affect the vegetation adversely. In Sudan agriculture, particularly shifting cultivation and rainfed-mechanized farming have been expanded at the expense of natural woodland. Natural forests in the clay plain of Sudan contribute by 76% of the total Sudan energy consumption [5] and this in turn accelerates the rate of deforestation. On the other hand, grazing in dry areas depends mainly on leguminous tree species of which *A. seyal* is palatable at all stages of its development.

Fire is a major ecological factor in several ecosystems it is an integral part of the evolutionary forces, which have shaped these ecosystems. Although it might acted primarily through species extinction, retaining species with traits adaptive to several disturbances and not specifically to fire [6]. The biological traits most influenced are reproductive, which permit a rapid re-establishment or resprouting and/or germination of seeds after fire [7].

Effective management of some plant communities is dependent on understanding of seed bank dynamics. Lawton and Putz [8] investigated the seed bank following slash and burn; their investigation revealed that most woody vegetations have originated from the seed bank. However, no plant community is entirely undisturbed. The scale, severity and timing of disturbances are crucially important. In general, sense, the role of seed bank in vegetation dynamics is intimately connected with disturbances such as fire [9]. West [10], Young et al, [11] concluded that slash and burn reduces the seed bank to less than 50% of its original size, and about 85% of the surviving seeds subsequently germinate. The persistence of the seeds in the soil is a major component of plant succession and plays substantial role in evolution of plant communities.

Sandbank of *A. seyal* is relatively small; this is mainly based on the data from dryland forest ecosystem, which generally seem to have low number of seeds/m². Such investigations in dryland ecosystems revealed quite low densities. Mustafa [12] found about 20 seeds/m² under the canopy of *A. seyal* in Sudan. However, in Ghana Hall and Swaine [13] reported 100 to 170 seeds/ m², in Kenya Kaaraka [14] found a maximum of 6 seeds/ m² under the canopy of *Acacia spp*. Dryland ecosystems, in general, seem to have smaller seed banks. This may be due to seed losses through fire, pathogens or through germination in response to favorable conditions.

Recruitment of sandbank is restricted to periods with favorable conditions of soil parameters that may control seed germination. Recruitment of Acacia seedlings in Sudan is much lower than mortality and most of the mortality is ascribed to human activities, recruitment is apparently confined to years with relative high precipitation [15]. The situation needs efforts and actions to formulate measures to regulate human pressure on natural forests and to restore the vegetation.

Materials and Methods

The present study was conducted in flat opened yard at Wad Medani town (long. 33º 29' N and Lat. 14º 23' E). Soil is clay, forming a network of cracks when drying. It is alkaline and of low permeability and organic matter content. The mean monthly temperature is 28.3ºC, monthly average of the daily maximum temperature is 37.7ºC and corresponding minimum is 18.8ºC when measured during the period of study in November 2002.

Samples of dry grasses were collected from Okalma forest in the clay plain of Sudan at long 33º 84' N and Lat 13º 05' E. The grasses were clipped at the ground level from five randomly located quadrates of one square meter in area. Clipping was done in October 2002 to avoid grazing. Weights of the loops were measured after drying to calculate the average fuel amount per quadrate, which was found to be 1.5 kg/ m².

The study was conducted on flat land free of trees. The experiment was layed out in split plot design. Consisted of four blocks, the soil of each was ploughed and leveled to ensure its freedom of fuel and seeds, each block consisted of four plots each of three-square meters in area. The plot was uniformly covered with 0.0, 1.0 or 1.5 kg of dry grasses. Each plot was divided into three subplots to incorporate seeds of *A. seyal* at 0.0, 5 or 10 cm of soil depth. About 250 seeds of initial viability of 89% were incorporated in each subplot at the prescribed depth.

Fire was set in the plot and immediately after burning air temperature, soil temperature at 0.0, 5 and 10 cm soil depth, rate of spread (cm s^{-1}) and residence time (s^{-1}) of fire were measured. Maximum and minimum temperature thermometers, soil temperature thermometer, measuring tape and stopwatch were used (Table 1,Table 2).

After 48 h from burning, the soil of each plot was collected to the depth of seed position and sieved for seed extraction and counted. Recovered seeds were grouped into persistent and perished seeds. The persistent seeds were those that looked healthy from the appearance, while the perished seeds were those charred or lost.

Percentage of persistent, charred and lost seeds were calculated to normalize the variance, the data were transformed to using arcsine transformation in case of the persistent seeds and root transformation in case of perished ones. Analysis of variance (ANOVA) was performed using MSTAT package to estimate the significance of fire intensity on seed bank at the various soil depths. Means of the treatments were segregated using studentzed T-test.

Hundred persistent, healthy seeds of no cracks in their coats, which recovered from each subplot, were treated by (98%) Sulphuric Acid for five minutes and then germinated on moist filter paper placed into Petri dishes in the laboratory and watered regularly with distilled water. The seeds that produced a 1-mm radicle were considered germinable, daily counted and discarded for a period of one month. The remaining seeds were first soaked in water for 5 h at 30 °C, then they opened along the cotyledons attachment to expose the embryo to the 2-3-5 Triphenyl Tetrazolium Chloride of 1% concentration for two hours under normal room conditions. The seeds were then taken

Table 1: Soil temperature (ºC) measured at various soil depths immediately after burning.

Soil depth (cm)	Soil temperature (ºC)			
	Grass weight (kg)			
	0.0	0.5	1.0	1.5
0	32.5	44.4	45.9	46.1
5	26.0	40.6	40.9	42.5
10	26.9	41.5	41.5	39.9

Air temperature 28.3 ºC
SE ± 3.2

Table 2: Rate of fire spread (cm s^{-1}) measured immediately after burning.

Soil depth (cm)	Rate of fire spread (cm s^{-1})			
	Grass weight (kg)			
	0.0	0.5	1.0	1.5
0	0	21 ± 1.8	22 ± 1.3	23 ± 1.3
5	0	21 ± 2.8	21 ± 3.3	22 ± 2.5
10	0	21 ± 2.2	21 ± 2.8	21 ± 8.0

(Means ± SD)
SE ± 2.9

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out of the chemical, washed with water and cut through embryo. The seeds that showed red colour in their embryo were graded as viable seeds.

The percentages of germinated and viable seeds were calculated in each sample. The data were transformed to arcsine values. Then ANOVA was run in order to estimate the magnitude of effect of each treatment at various levels. LSD test was used to segregate differences between the means.

Results and Discussion

Recovered seeds

Results of the study showed that after setting fire, about 73% of the seeds buried in the soil at various depths were recovered (Table 3). Percentages of the seeds recovered from all plots that subjected to fire were significantly (0.5) less than those recovered from unburned plots. Relating the percentage of the recovery of the seeds to various burying depths, the differences between the means were found not significant (0.5). It was also revealed that the impact of the fire on the seeds was statistically the same at all depths.

About 2% of the recovered seeds were charred as seen by the naked eye (Table 4). Moreover, 3% of the buried seeds lost (Table 5). The number of the charred seeds significantly (0.5) increased as the grass weight increased. The same trend could be seen in the treatment of the burying depth, but the percentage of the charred seeds at the top soil (0.0 cm) was four times greater than that in the other depths. The percentage of the lost seeds increased with increasing soil depth, this was mainly attributed to the presence of soil cracks below 10 cm depth which made some of the seeds went deep in the soil, but the differences between the means were not significant (0.5).

Germination and viability of the recovered seeds

Table 6 showed that the germination percentage of the recovered seeds did not exceed 53%. It decreased as the fuel mass increased, but the differences between the means were not significant. However, the germinability of the seeds found on the top soil was significantly (0.5) reduced by fire compared to the means of the seeds in other soil depths.

The conducted physiological test by germination and tetrazolium showed that the viability of the recovered seeds decreased from 89%, (initial viability), to 55% (Table 7). The viability of the seeds found on soil surface was significantly (0.5) reduced compared to that of the seeds buried at various soil depths, but the increase in soil depth did not cause a significant reduction in the viability of the seeds.

In this study, it was proved that fire has damaged some of the

Table 3: Percentage of recovered seeds of *Acacia seyal* at various depths (Means ± SD). The data are given after arcsine transformation.

Soil depth (cm)	Percentage of recovered seeds				
	Grass weight (kg)				
	0.0	0.5	1.0	1.5	mean
0	81.3± 6.7	72.1 ± 4.6	70.7 ± 10.2	65.2 ± 3.4	72.3 b
5	78.3 ± 1.7	74.4 ± 4.7	76.8 ± 2.9	73.9 ± 5.0	75.9 b
10	76.3 ± 1.4	67.5 ± 1.7	71.4 ± 1.8	71.3 ± 4.1	71.6 b
mean	78.6 a	71.3 a	72.9 ab	70.1 b	73.2

SE ± 2.47 for grass weigh
SE ± 1.52 for soil depth

Table 4: Percentage of charred seeds of *A.seyal* at various depths (means ± SD). The data are given after root transformation.

Soil depth (cm)	Percentage of charred seeds				
	Grass weight (kg)				
	0.0	0.5	1.0	1.5	mean
0	1.0 ± 0.0	5.3 ± 0.15	5.8 ± 0.19	6.1 ± 0.50	4.5 a
5	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	2.0 ± 0.90	1.2 a
10	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	1.0 a
mean	1.0 a	2.4 a	2.6 a	3.0 a	2.2

SE ± 0.05 for grass weigh
SE ± 0.05 for soil depth

Table 5: Percentage of lost seeds of *A. seyal* at various depths (means ± SD). The data are given after root transformation.

Soil depth (cm)	Percentage of lost seeds				
	Grass weight (kg)				
	0.0	0.5	1.0	1.5	mean
0	1.0 ± 1.7	3.3 ± 1.5	3.7 ± 2.3	4.3 ± 1.0	3.3 a
5	2.2 ± 0.5	2.9 ± 1.4	2.6 ± 0.8	2.0 ± 1.5	2.7 a
10	2.6 ± 0.5	3.9 ± 0.5	3.3 ± 0.3	3.4 ± 1.3	3.3 a
mean	2.2 a	3.4 a	3.2 a	3.5 a	3.1

SE ± 0.3 for grass weigh
SE ± 0.2 for soil depth

Table 6: Germination percentage of recovered seeds of *A. seyal* at different soil depths (means ± SD). The data are given after arcsine transformation.

Soil depth (cm)	Germination percentage				
	Grass weight (kg)				
	0.0	0.5	1.0	1.5	mean
0	64.3 ± 4.47	42.5 ± 3.73	28.7 ± 4.90	30.3 ± 5.48	41.5 b
5	60.8 ± 6.93	59.4 ± 4.83	58.9 ± 7.21	56.6 ± 3.93	58.9 ab
10	58.0 ± 3.76	56.9 ± 6.62	64.5 ± 7.46	61.0 ± 1.48	60.1 a
mean	61.0 a	52.9 ab	50.7 b	49.3 b	52.5

SE ± 3.1 for grass weight
SE ± 1.8 for soil depth

Table 7: Viability percentage of recovered seeds of *A. seyal* at different soil depths (means ± SD). The data are given after arcsine transformation.

Soil depth (cm)	Viability percentage				
	Grass weight (kg)				
	0.0	0.5	1.0	1.5	mean
0	65.1 ± 4.0	42.5 ± 3.73	29.4 ± 4.83	35.3 ± 11.20	43.0 b
5	61.5 ± 7.04	60.7 ± 4.63	59.9 ± 7.19	56.7 ± 3.88	59.7 ab
10	58.5 ± 3.80	58.1 ± 6.40	65.5 ± 8.57	62.0 ± 1.79	61.0 a
mean	61.7 b	53.7 b	51.6 b	51.3 b	54.6

SE ± 3.5 for grass weight
SE ± 1.5 for soil depth

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seeds. This goes with results of many investigations that fire may shape the vegetation pattern [6]. The damage of *A. seyal* seeds by fire should be taken into consideration, together with the fluctuation of the seed production when planning for plantation establishment. Seed production in *A. seyal* fluctuates from one year to another due to the unstable environmental conditions of the dryland.

The result of this study are in agreement with the finding of Hassan and West [10] who stated that fire damages the seed stored on the soil surface. The greater the fuel mass the hotter the fire and then more seeds would be burned. It was clear in this study that the effect of fire was confined to the top layer of the soil. This suggests that a significant damage may need more fire residence to permit the conductance of heat deep into the soil to produce adverse effects on the seeds. Although only about 2% of the seeds had been burned or charred, this amount is large enough if we know that about 95% of the seeds incorporated in the soil could be depleted by germination and suffocation within three years (Mustafa 1997). Another point supporting the danger of fire on the soil seedbank is that the damage is confined to the soil surface, which embodies the potential soil seedbank that would be developed into plants.

In the present study the viability of the seeds buried at all depths decreased by 34% after fire incidence. The significant reduction occurred in the viability of the seeds broadcasted on the soil surface, is strongly supported by the finding of Young et al, [11] who assured destruction of the seeds on top of soil surface by fire, and the effect will be so serious if the fire is severe and resident for long time.

This study showed that fire has decreased the germinability of the seeds of *A. seyal* particularly those on top of the soil. This could be attributed to the fact that fire may cause damage to the embryo; moreover, it was found that the germination of seeds extracted from burned plots was lower than that of unburned seeds. Many plant species have seeds, which require heating or other means of seed coat scarification for germination. Mustafa [12] has stated that the seeds of A. seyal have coat-imposed dormancy that may maintain the viability of the seeds for long time waiting favorable conditions to germinate. However, germination of the dormant seeds is somehow difficult unless their dormancy is broken. Naturally, this brought about by many biotic and abiotic factors such as temperature and pathogens. However, this study revealed that the heat released from high fuel burning have reduced germination of the seeds particularly those on the soil surface, compared to the germination of the seeds recovered from other soil depths.

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