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THE INFLUENCE OF PINE ASH ON THE GERMINATION AND EARLY GROWTH OF *PINUS HALEPENSIS* MILL. AND *CISTUS SALVIIFOLIUS* L.

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ABSTRACT

Black ash circles are found under the burned canopies of big dead pine trees up to three years after fires. Similar circles are formed as the result of a spatial pattern of seedling recruitment after fires. It has been suggested that the accumulation of ash around the burned trees, and the differential reaction of seed germination to ash, may be a major cause for the spatial pattern of seedling recruitment after fires. The results of germination experiments in pots prove that thick cover of ash has a negative effect on germination of *Pinus halepensis* Miller, and on germination and growth of *Cistus salviifolius* L. Ash solutions in petri dishes had no effect on germination and growth of both species. *Pinus* seems to be more well adapted than *Cistus* to germination and growth in sites with high amounts of ash after fire. Our results support the hypothesis that the ash around the burned pine trees, and the differential reaction of plant species to the ash may explain the spatial pattern of seedling recruitment after fire. We suggest that the relatively high resistance of pine seed germination to osmotic stress is an adaptation to post fire germination rather than to germination in arid zones.

KEYWORDS fire, ash, germination, growth, *Pinus*, *Cistus*.

INTRODUCTION

Mediterranean type ecosystems all over the world are exposed to fires. As a result, all plant species have different traits which enable their populations to survive under different fire regimes. These traits can be regarded as a general adaptation for overcoming disturbances (Trabaud, 1987). Keeley (1991) combines all such traits into two syndromes: (1) the fire persister or non-refractory seed syndrome includes species that are resilient to frequent fires through vegetative resprouting, but requires fire- free periods for recruiting new seedlings. The seeds of most species are big, dispersed by animals, lack dormancy and germinate soon after dispersal. (2) The fire recruiter or refractory seed syndrome includes species with seeds that are in most cases small, not dispersed by animals and cued to germinate in the first rainy season after the fire. The only fire-related stimuli mentioned by Keeley (1991) are heat shock and incubation with charred wood.

Black ash circles are found under the burned canopies of big dead pine trees up to three years after fires (Lahav 1988). Such circles are formed as the result of a spatial pattern of seedling recruitment after fires. Seedlings of annual species are almost always absent; seedlings of Pinus and Cistus are present in much lower densities under the burned trees than elsewhere, while Rhus seedlings usually grow only near the burned pine trunks (Ne'eman et al. in press). It has been suggested that the accumulation of ash around the burned trees, and the differential reaction of seed germination to ash, may be a major cause for the spatial pattern of seedling recruitment after fires (Ne'eman et al. in press).

The aim of this work is to study the influence of pine ash on the germination of Pinus halepensis Miller and Cistus salviifolius L.

MATERIALS AND METHODS

Seeds of Pinus halepensis Miller and Cistus salviifolius L. were preheated at 100°C for 15 minutes. This was done in order to get a high percent of germination in the controls. Pinus halepensis' small twigs and needles were completely burned into fine ash which was used in the experiments. Two kinds of germination experiments were performed:

A) Seeds were sown in petri dishes with different concentrations of pine ash solutions. The ash solutions were prepared by mixing 30 g (100 cc) of ash with 100 , 200 and 500 cc of distilled water (treatment 3, 2 and 1 respectively). Distilled water was used as control. The osmotic value of the solution used in treatment 3 was equivalent to 0.356 osmole. Distilled water was used as control. Ten seeds were put on filter paper in each dish. The seeds were sown on February 10, 1991 and were left in light at room temperature (18°c) for 37 days. The petri dishes were kept wet by adding small amounts of fresh ash solution in the same concentration. The number of the seedlings was counted and their root and shoot lengths were measured at the end of the experiment.

B) Seeds were sown in 1 litre pots filled with 13 cm of terra-rossa soil which was covered by 1, 2 and 5 cm of ash in the treatments marked ash1, ash2 and ash5 respectively. No ash was added to control pots. The osmotic value of the runoff solution at the bottom of the pots covered with 5 cm of ash at the beginning of the experiment was equivalent to 1.007 osmole. 20 seeds were put on top of the ash in each pot on March 18, 1991 and left outdoors until July 1, 1991, in a rain protected and unheated greenhouse. The pots were watered up to saturation and were kept wet by the addtion of water up to saturation twice a week. The temperatures were 4-26°C in March, 7-31°C in April, 8-33°C in May and 10-34°C in June. The seedlings were counted, and their height was measured four times during this period.

The main components of the ash before and after the experiment were analyzed routinely by a field service laboratory of The Israel Ministry of Agriculture-MIGAL (Table 1).

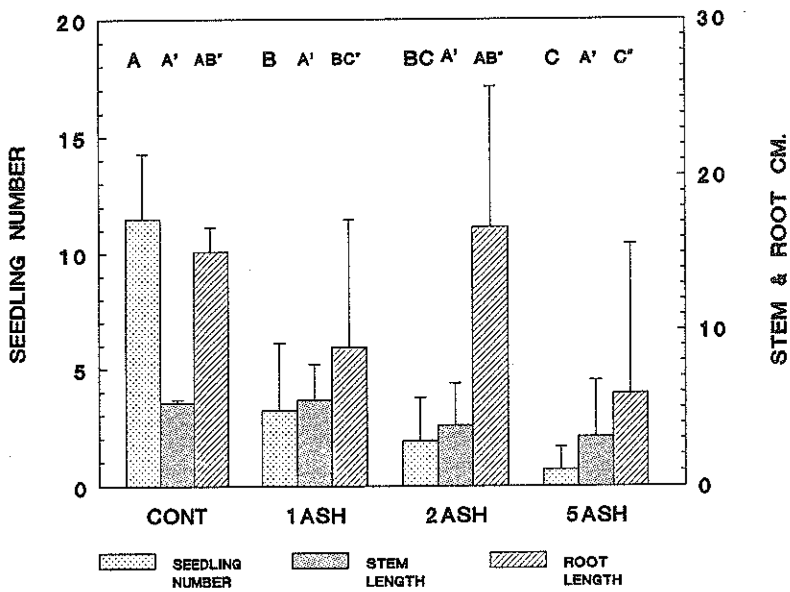
Table 1.
Some properties of the ash before and after its use in the pot experiments.

	Conductivity Mmho/cm	N-NH4 (µg/g)	N-NO3 (µg/g)	Soluble cations (µg/g) P	K	Mn	Zn	Cu
Before	10.8	8.2	5.8	876	840	18.8	65.0	2.3
After	2.5	3.4	80.3	481	130	8.2	19.5	3.3

RESULTS

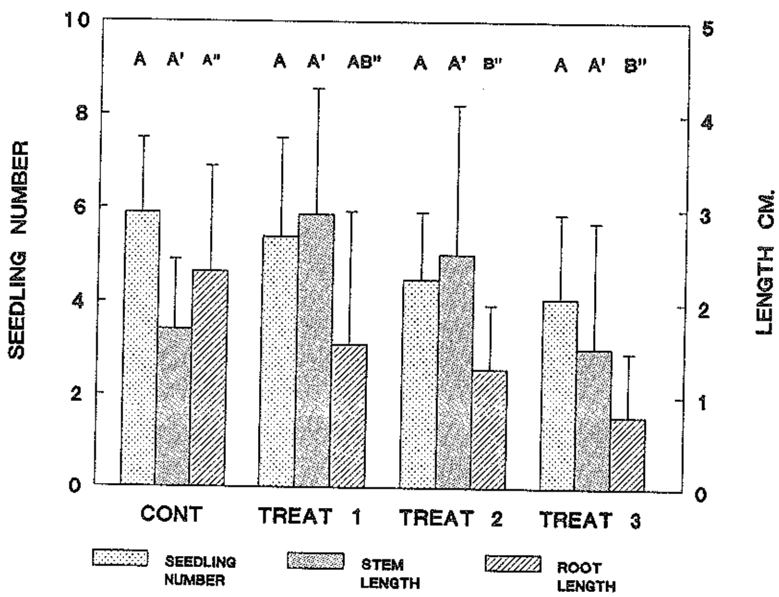
Germination of _Pinus_ seeds was inhibited by ash, both in pots and petri dishes. The reduction of the percent of seed germinations in pots was between 72.2% and 94% on 1 and 5 cm of ash cover respectively, and was statistically significant (Fig. 1).

Figure 1. Number and height of _Pinus halepensis_ seedlings germinated out of 20 seeds in pots, on top of different ash layers: 1cm (1 ASH), 2cm (2 ASH) and 5cm (5 ASH), compared with control with no ash (CONT). Error bars represent standard deviation. Columns with identical letters and symbols are not different according to Duncan test ($P>0.05$). ANOVA analysis for seedling number $F_{(3,36)}=47.03$, $P=0.0001$; for stem length $F_{(3,36)}=2.04$, $P=0.1260$; and for root length $F_{(3,36)}=3.94$, $P=0.0158$.



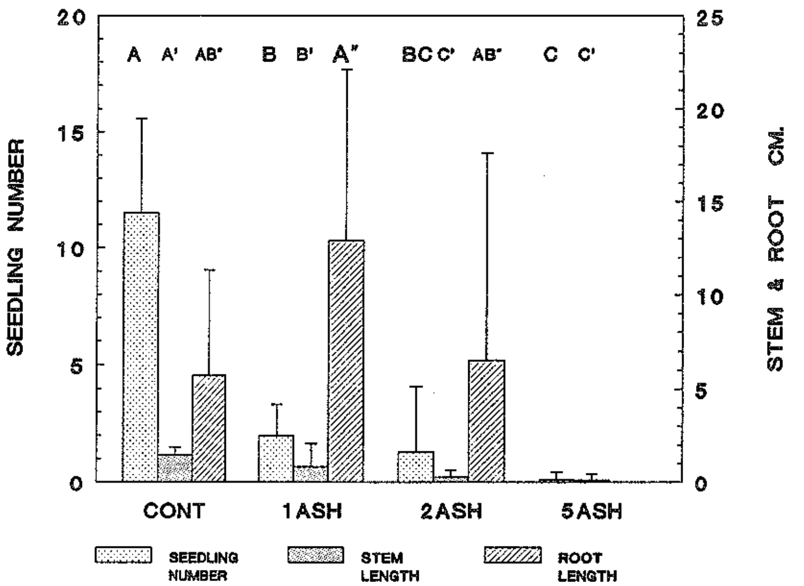
The reduction of seed germination in petri dishes was between 8.5% and 30.5% in the low and high ash concentrations respectively, but was not statistically significant (Fig. 2). Pine shoot growth was insignificantly enhanced (71.9%-47.4%) in the low concentrations of ash in petri dishes but was decreased (12%) in the high concentration (Fig. 2). Shoot growth in pots was insignificantly reduced between 28% and 41% in 2 cm and 5 cm of ash respectively (Fig. 1). Pine root growth, in pots, was significantly reduced by 61% in the 5 cm ash treatment; the differences between the control and 1 cm and 2 cm ash were big but insignificant.
Pine root growth, in petri dishes, was drastically and significantly reduced between 35.5% and 66.5% in the low and high ash concentrations respectively (Fig 2).

Figure 2. Number and length of stem and root of *Pinus halepensis* seedlings germinated out of 10 seeds in petri dishes in saturated ash solution (TREAT 3), in 50% saturated ash solution (TREAT 2), in 20% saturated ash solution (TREAT 1) and in water (CONT). Error bars represent standard deviation. Columns with identical letters and symbols are not different according to Duncan test ($P>0.05$). ANOVA analysis for seedling number $F_{(3,37)}=2.28$, $P=0.0959$; for stem length $F_{(3,37)}=2.79$, $P=0.0537$; and for root length $F_{(3,37)}=4.18$, $P=0.0120$.



Reduction of the number of *Cistus* seed germinations in pots was between 74% and 99% on 1 cm and 5cm of ash respectively, and was statistically significant (Fig. 3). No effect of ash solution on germination was detected in petri dishes (Fig. 4). Shoot growth was significantly reduced between 42.8% and 93.1% by 1 cm and 5 cm of ash in pots (Fig. 3). No effect of ash solutions on shoot growth was found in petri dishes (Fig. 4). Root elongation of Cistus was significantly inhibited in petri dishes between 48.3% and 31.7% by different concentrations of ash solutions (Fig 4). Big but not significant differences in root growth were found in pots (Fig. 3)

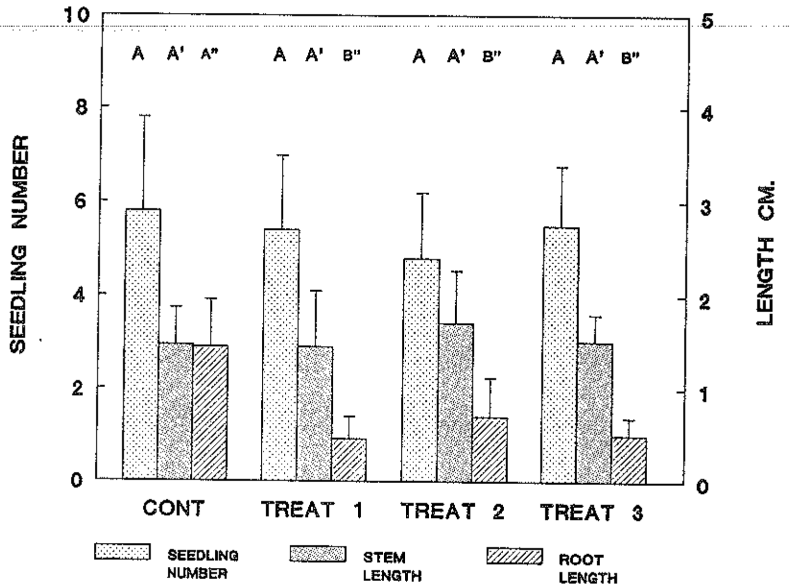
Figure 3. Number and height of Cistus salviifolius seedlings germinated out of 20 seeds in pots, on top of different ash layers: 1cm (1 ASH), 2cm (2 ASH) and 5cm (5 ASH), compared with control with no ash (CONT). Error bars represent standard deviation. Columns with identical letters and symbols are not different according to Duncan test ($P>0.05$). ANOVA analysis for seedling number $F_{(3,36)}=40.29$, $P=0.0001$; for stem length $F_{(3,36)}=17.85$, $P=0.0001$; and for root length $F_{(3,36)}=4.66$, $P=0.0075$.



The results demonstrate the negative effect of a thick layer of ash and high concentrations of ash solutions on germination of both species. The effect on shoot growth and root elongation seems to be more variable and concentration dependent. Even though thick ash cover had a negative effect on germination and growth of both species, Pinus seems to be more resistant than Cistus.

The chemical analysis of the ash (Table 1), shows a 4.3-fold reduction in conductivity which is the result of ditching nutrient ions by watering. Thus the concentrations of the nutrients in the soil decreased during the experiment according to their solubility. The increase in NO_3^- seems to be the result of nitrification activity of soil microorganisms.

Figure 4. Number and length of stem and root of <u>Cistus salviifolius</u> seedlings germinated out of 10 seeds in petri dishes in saturated ash solution (TREAT 3), in 50% saturated ash solution (TREAT 2), in 20% saturated ash solution (TREAT 1) and in water (CONT). Error bars represent standard deviation. Columns with identical letters and symbols are not different according to Duncan test ($P>0.05$). ANOVA analysis for seedling number $F_{(3,36)}=0.70$, $P=0.5567$; for stem length $F_{(3,36)}=0.63$, $P=0.5977$; and for root length $F_{(3,36)}=15.97$, $P=0.0001$.



DISCUSSION

Ash is not mentioned as having a regulatory effect on seed germination in general (Mayer and Poljakoff-Mayber, 1982) and on germination of post fire seeders in particular (Keeley, 1991). Differences in ash quantity and quality were found under oak trees, under pines and in open areas on Mount Carmel after fire. The ash collected right after fire and burned soil collected two years later had a stimulating effect on wheat and alfalfa growth as a result of improved mineral nutrition (Kutiel and Naveh, 1987a and 1987b).

Our results agree with those of Lahav (1988), who demonstrated the inhibition of seed germination by ash. The inhibition of germination through a high amount of ash may be compared to the inhibition of germination by salt. Thus the inhibition may be the result of prevention of water uptake by the embryo due to the high osmotic (or low water) potential of the medium, or by poisoning of the embryo owing to the toxic effect of certain ions (Waisel, 1972).

The germination of C. incanus ssp. creticus was found to be completely suppressed by 0.6M manitol solution (Thanos and Georgiou, 1988). A similar concentration caused only 50% inhibition of germination in P. halepensis and P. brutia (Thanos and Skordilis, 1987). Our results bring evidence that Pinus is better adapted than Cistus to germination and growth in sites with high ash cover. The relatively high resistance of pine germination to osmotic stress was interpreted as an adaptation to the dry Mediterranean climate (Schiller and Waisel, 1989). The germination of the above-mentioned Pinus and Cistus species occurs in winter when the water potential of the soil is relatively high. All these species are post fire seeders (Naveh, 1973; Lahav, 1988 ; Trabaud and Oustric, 1989) which germinate even in sites covered with ash. Therefore we suggest that the relatively high resistance of pine germination to osmotic stress is an adaptation to post-fire germination rather than to germination in arid zones.

Our results support the hypothesis that the ash around the burned pine trees, and the differential reaction of plant species to the ash may explain the spatial pattern of Pinus and Cistus seedling recruitment after fire (Ne'eman, Lahav and Izhaki in, press). The results show reduction of shoot growth in most ash treatments; the two low concentrations in petri dishes caused growth enhancement indicating the positive effect of low ash levels on pine growth. Such conditions may occur in nature during the second and third growing seasons, and may explain the faster development of the pine seeds which do succeed to germinate in the proximity of the old burned pine trees (Kutiel and Kutiel, 1989 ; Ne'eman, Lahav and Izhaki, in press). The ecological and practical significance of this phenomenon seems to be that these pine seedlings will grow to build the next generation of the new pine forest.

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