Ecological Engineering 95 (2016) 138–142

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Short communication

Effects of straw mulching on initial post-fire vegetation recovery

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ARTICLE INFO

Article history:
Received 3 January 2016
Received in revised form 10 May 2016
Accepted 15 June 2016
Available online 2 July 2016

Keywords:
Wildfire
Straw mulch
Soil seed bank
Vegetation recovery
Nonnative species

ABSTRACT

Straw mulching is increasingly used after high severity wildfires for reducing post-fire runoff and erosion but can alter post-fire vegetation regeneration. However, information about the extent to which mulching affects the recovery of native vegetation is inconclusive. The soil seed bank plays an important role in the resilience of frequently disturbed shrubland communities but little is known about how it is affected by mulching treatments. In this study, we assessed the effects of straw mulching (2.0 Mg ha^{-1}) on the recovery of vegetation after a wildfire in Galicia (NW Spain). For this purpose, we carried out a greenhouse and field-based study to evaluate the effects of mulching applied immediately after fire on the soil seed bank and recovery of vegetation cover in a shrubland area during the first year after wildfire. In the greenhouse, there were no differences in the total number of seedlings that emerged from the soil seed bank of mulched and untreated samples (634 seedlings m^{-2} vs 731 seedlings m^{-2}). Species richness increased from 22 in untreated burned soils to 24 species in the mulched, burned soils. In the field, straw mulching favoured plant establishment and recovery of vegetation cover. At the end of the first post-fire year, plant cover was significantly higher (63%) in the mulching treatment compared to the untreated one (44%). Mulching did not affect species composition, and there was little evidence of the presence of non-native species. The results indicate that, in the present case, straw mulching immediately after the fire favoured recovery of plant cover in the first year after the fire by conserving the soil moisture.
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1. Introduction

Wildfire is a major agent of land degradation in wildland environments because of the erosive response of burned soils (Shakesby and Doerr, 2006). Significantly increased runoff and erosion have been observed after some wildfire especially on steep slopes where soils remain bare post-fire (Benavides-Solorio and MacDonald, 2005; Fernández et al., 2011; Vega et al., 2015; Fernández and Vega, 2016) with loss of macronutrient and trace elements (Gómez-Rey et al., 2013; Gómez-Rey et al., 2014).

Agricultural straw is increasingly applied after wildfires to reduce soil erosion potential (Wagenbrenner et al., 2006; Fernández et al., 2011; Vega et al., 2015) and maintain soil quality (Barreiro et al., 2015). However, information about how mulching affects vegetation recovery and species composition is inconclusive. Neutral (Fernández et al., 2011; Vega et al., 2014; Fernández and Vega, 2016) to positive effects of mulch on vegetation establishment and growth have been reported, particularly in dry sites (Badía and Marti, 2000; Peterson et al., 2009), and even in shrubland communities dominated by resprouters (Fernández and Vega, 2014; Vega et al., 2015) using mulching rates around 2.0–2.5 Mg ha^{-1}, suggesting than on these dry sites, mulch helps to conserve soil moisture and does not prevent seedling emergence. However, inhibition of plant growth has also been reported (Kruse et al., 2004; Dodson and Peterson, 2010) and attributed to alterations in the soil moisture regime, lack of light availability, and to the mulch acting as a physical barrier reducing seedling emergence. None of the above mentioned studies focused on how straw mulching affected the soil seed bank, which is known to be important for post disturbance vegetation recovery (Thompson et al., 1997). Greater insight into the effects of soil stabilization treatments on soil seed bank will help to select valid criteria for the analysis of possible environmental impacts.

In the period between 2001 and 2010, approximately 8000 fires occurred every year in Galicia, representing 46% of all forest fires in Spain (MMA, 2010). In the same period, more than 70% of the wildland area burned annually in Galicia was shrubland (MMA, 2010). Shrubland ecosystems are characterized by the presence of two

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http://dx.doi.org/10.1016/j.ecoleng.2016.06.046
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main types of plants: obligate seeders, which are killed by fire and depend on recruitment from seeds for persistence, and resprouters, which regrow vegetatively from buds after fire. *Cytisus striatus* (Hill) Rothm, *Pterospartum tridentatum* (L.) Willk, and *Halimium lasianthum* spp. *alyssoides* (Lam.) Greuter are common components of shrubland areas in northern Spain. They are representative of each of the above-mentioned post-fire regeneration strategies. *Cytisus striatus* is an endemic species from the Iberian Peninsula, and its post-fire regeneration depends almost entirely on germination. The mulch cover can alter micro-environmental conditions and affect obligate seeders recovery by reducing seed germination (Santana et al., 2014). Wildfires often favour the establishment of non-native species (Hunter et al., 2006) and mulching may also facilitate their introduction or the establishment of locally present non-native species (Kruse et al., 2004) altering plant community composition.

We monitored the composition of the emerged seedlings from the soil seed bank and its similarity to the above ground vegetation after applying straw mulch in the first year after a fire in a shrubland area in Galicia. Our initial hypotheses were as follows: a) Mulching treatment affects seedling emergence and b) Mulching application affects the recovery of vegetation and plant community composition.

2. Methods

2.1. Study site

The study was carried out in the municipality of Saviñao (UTM 29 T 06133–47247; 530 m a.s.l.) in the province of Lugo (Spain). A recently burned shrubland area on a relatively homogeneous slope of 40% was selected for study in the summer of 2012. The study is part of an integrated investigation on the effects of soil stabilization treatments on vegetation, soil properties, soil erosion and nutrient budget (Lombao et al., 2015).

The shrubland was dominated by *Cytisus striatus* (Hill) Rothm. The climate in the area is Mediterranean, with an average rainfall of about 900 mm year^{-1} and a mean annual temperature of 12.7 °C. The soil, developed on grey slate, is classified as Alumi-umbric Regosol (FAO, 1998).

2.2. Experimental design and field measurements

Immediately after the wildfire, eight experimental plots (40 × 10 m each) were established in a randomized block design with the longest dimension perpendicular to the slope contour. The blocks had an area of about 0.2 ha each and were separated from each 100 m. Two treatments were assigned at random in quadruplicate: straw mulch (spread manually at a rate of 2.0 Mg ha^{-1}) and control (untreated burned soils). The mean mulch cover of soil immediately after application was 85%. One year after treatment application, mulch cover averaged 50%.

Ten subplots (1 m × 1 m) were located at random in each experimental plot. Vegetation cover was measured within the 1 m × 1 m subplot with the help of a 0.1 m × 0.1 m grid at the end of the first post-fire year. All plant species were identified, and the number of individual seedlings of each species was counted. The nativity of the species was defined according to Sanz et al. (2004).

2.3. Seedling emergence

The composition of the soil seed bank was estimated by the seedling emergence technique (Brown, 1992). Soil samples (0.2 m × 0.25 m width and 5 cm depth) were collected immediately after application of mulch adjacent to each subplot. The soil samples (n = 80; 40 mulched and 40 untreated soil samples) were collected carefully to ensure that the soil structure remained intact. The samples were placed on trays and transported to the laboratory and then laid out in a greenhouse. All roots and bulbs or tubercles were discarded. Natural photoperiods were maintained in the greenhouse and the samples were watered every two days. During the study period, the relative humidity in the greenhouse varied between 60 and 80%, and the temperature varied between 12 °C and 21 °C. Mulch cover in the treated samples was 60% at the end of the period of study. These greenhouse conditions were used to favour germination of the seeds and avoid the effects of environmental variation (weather and animals) on seedling emergence compared to the field.

The number of emerged seedlings was recorded every three days during the first three months and then every seven days over a period of nine months. Each newly emerged seedling was assigned an identification number to avoid errors in counting.

Table 1
Mixed-model tests of fixed effects of mulching treatment on greenhouse and field vegetation variables.

	F	P
Greenhouse		
Total seedling density	0.948	0.3302
Cytisus striatus seedling density	1.385	0.2392
Woody shrub seedling density	3.551	0.0595
Species richness	10.679	**0.0011**
Field		
Total vegetation cover	26.801	**<0.0001**
Total plant density	7.178	**0.0074**
Cytisus striatus seedling density	0.8233	0.3642
Woody shrub seedling density	0.7344	0.3915
Species richness	13.452	**0.0002**
Similarity index	3.362	0.0667

Numerator degrees of freedom = 1; denominator degrees of freedom = 79. Significant effects are indicated in bold type.

2.4. Statistical analysis

The similarity of the species composition in the emerged seedlings in the greenhouse and above-ground vegetation in the field was assessed by the Sorensen's similarity index (Sorensen, 1948) by only considering species presence. The index values are expressed as percentages of similarity.

A generalized linear mixed effects model was used to examine how mulching affected the variables in the greenhouse (total number of emerged seedlings, number of emerged *Cytisus* seedlings, number of emerged woody shrub seedlings and species richness) and in the field (total number of emerged seedlings, number of emerged *Cytisus* seedlings, number of emerged woody shrub seedlings, species richness, total vegetation cover) and the similarity index. The treatments (mulching and untreated control) were included as categorical fixed factors. Experimental plot and subplot were considered as random effects within each model.

The R statistical package (Core Team Development, 2014) was used for all statistical analyses.

3. Results

3.1. Greenhouse measurements

The number of seedlings that emerged from the soil seed bank after mulching did not differ (Table 1) from the number of seedlings that emerged from the untreated one (Table 2). In both cases, the density of *Cytisus striatus* seedlings was higher than that of other species that emerged (Table 2), with no differences between treatments (Table 1). Species richness differed significantly between untreated and mulched soils (Table 1). Species composition was

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