Exotic annual control and the competitive release of native forbs: An example from the northwest Sonoran Desert.

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ABSTRACT

Exotic annual grasses and forbs have become increasingly dominant components of the Mojave and Sonoran Deserts. The purpose of this study was to evaluate the response of native forb species to the removal of exotic grasses and forbs. This experiment took place in a creosote bush scrub community located in Coachella Valley, California. The exotic grasses *Schismus barbatus* and *S. arabicus* were removed from experimental plots using the grass-specific herbicide Fusilade II®. The exotic forb *Erodium cicutarium* was removed by hand pulling. Three treatments that included a control, herbicide, and herbicide plus hand-weeding of *E. cicutarium* were implemented in shrub interspaces and understories. Removal of exotic grass species resulted in the increase of native forb % cover and biomass in both habitats. In interspaces, % cover of native forb species was only significantly greater in herbicide plus hand pulling of *E. cicutarium* treatments, suggesting that exotic forbs can be strong competitors with native forbs. These results demonstrated a strong positive response of native forbs to both exotic grass and exotic forb removal.

INTRODUCTION

Studies focusing on exotic annual grass invasion in the deserts of Southern California clearly indicate that significant alterations to the ecosystem and its processes have occurred. Consequences of exotic annual invasions have been an alteration in natural fire regime characteristics, including fire frequency, intensity, extent, and seasonality (Brooks et al. 2004). In addition, shrub based vegetation types have been converted to exotic annual grasses (Brooks and Matchett, 2003), native annual communities have been displaced (Beatley, 1966), and food quality has declined for important animals, such as the threatened Desert Tortoise (Nagy et al, 1998). The successful establishment and dominance of these exotic grasses have profound effects on the desert ecosystem, many of which are still undetermined.

While the invasion and impact of exotic grasses across desert landscapes has been dramatic and the focus of much research, the ecological impact of exotic forb species, such as *Erodium cicutarium*, may also be very important despite their relatively poor exposure in the scientific literature. *Erodium cicutarium* is an invasive forb that is abundant throughout the Mojave and Sonoran deserts, and is widespread in the United States (Hickman, 1996). Research that is focused not only on exotic grasses but also on exotic forbs may help us understand the importance of how these two functional types work in combination to alter the desert ecosystem. The goal of this study was to test the assumption that removal of exotic grasses and forbs simultaneously would result in optimal native annual response compared to removal of exotic grasses alone.

STUDY SITE

The study site was located in western Coachella Valley, approximately 6km Northeast of Palm Springs (Fig 1). Coachella Valley constitutes the northwestern most corner of the Sonoran Desert. The study site existed on a slightly sloped, west facing hillside that is part of the western most portion of the Indio Hills. The vegetation in this area was creosote bush scrub. *Larrea tridentata* was the dominant shrub and other shrub species were occasional, such as *Ambrosia dumosa*, *Krameria grayi*, *Ephedra californica*, and *Psorothamnus emoryi*. The annual vegetation at this site was dominated by *Schismus* spp. *Erodium cicutarium* was common and *Brassica tournefortii* was locally common in understory habitat. Common native forbs included, *Pectocarya* spp, *Chorizanthe brevicornu*, and *Chaenactis fremontii*, among others (Table 1).

This site experienced an exceptionally wet growing season in 2004-2005, with precipitation totaling about 280 mm, based on weather data collected at Palm Springs (http:www.noaa.gov) (Fig. 2). The average yearly precipitation for Palm Springs is about 66mm.

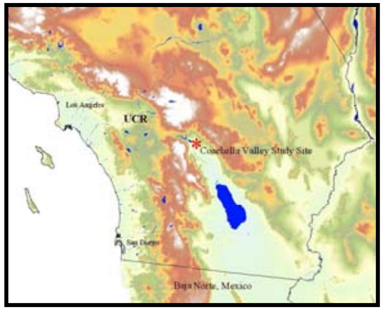

Fig 1. Map of Southern California showing location of the study site

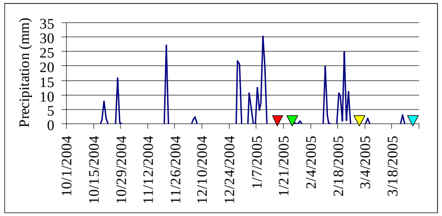

Fig 2. Graph of the 2004-2005 cool season precipitation totals. The total precipitation that fell before the treatments were implemented was about 195mm. Approximately 84 mm fell between implementation of the treatments (red triangle represents herbicide application on 1/19&21 and the green triangle represents *E. cicutarium* removal on 1/26) and the sampling of the interspace vegetation (yellow triangle on 3/1). About 5mm of additional precipitation fell between interspace sampling and the understory sampling (blue triangle) that took place on March 23, 2005.

Fig 3. On the left is a control plot and on the opposing right side is an herbicide treated plot.

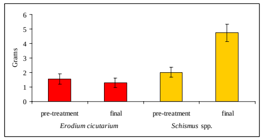

Fig 4. This graph illustrates the amount of interspace *E. cicutarium* and *Schismus* spp. biomass at treatment implementation time and at the end of the growing season.

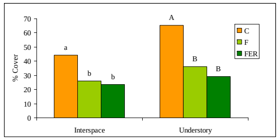

Fig 5. *Schismus* spp. % cover. Treatments: C = Control; F = Fusilade; FER = Fusilade and Erodium Removal. Significant differences between treatments are indicated by differing letters within similar micro-habitat type.

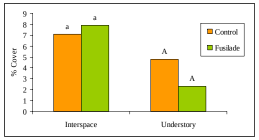

Fig 6. *Erodium cicutarium* % cover.

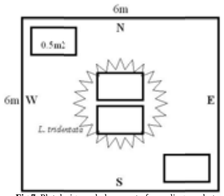

Fig 7. Plot design and placement of sampling quadrats.

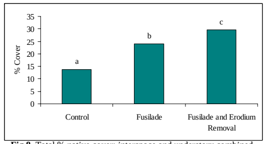

Fig 8. Total % native cover; interspace and understory combined.

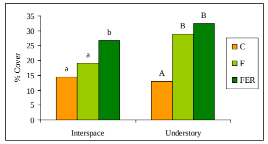

Fig 9. % Native cover by micro-habitat.

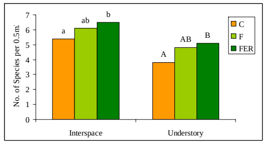

Fig 10. Native species richness per 0.5 m2.

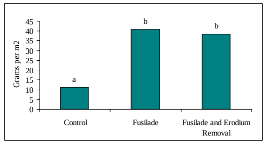

Fig 11. Native biomass per m2; interspace and understory combined.

Interspace Annual Community:

Species	IV	C	F	FER	P
Brassica tournefortii	F		**0.5**		
Erodium cicutarium	F	7	**7.9**	0.5	**< 0.0001**
Schismus spp.	C	**44.3**	26.1	23.4	**< 0.0001**
Achyronychia cooperi	FER	0.5		**0.7**	
Astragalus sp.	F		**0.5**		
Calyptridium monandrum	FER	0.5	0.5	**0.9**	
Camissonia claviformis	FER	0.7	0.8	**1.5**	0.089
Camissonia pallida	FER	0.5	2	**2.3**	
Chaenactis fremontii	FER	3.6	2.9	**5.4**	0.1534
Chorizanthe brevicornu	FER	1.8	2.7	**3.9**	**0.011**
Crassula connata	C	0.6	0.7	**0.7**	**0.0344**
Cryptantha angustifolia	FER	1.8	1.7	**3**	0.0845
Eriastrum sp.	F	0.8	0.9	**1.2**	
Eriogonum sp.	FER	0.5		**1**	
Euphorbia polycarpa	FER			**1**	
Filago depressa	F	0.7	0.8	**0.9**	0.6206
Lepidium lasiocarpum	F		0.5	0.5	
Loeflingia squarrosa	FER	0.5	1	**2**	
Pectocarya heterocarpa	F	0.9	1.6	**2**	0.0619
Pectocarya recurvata	FER	8.2	11.5	**13.9**	0.2219

Understory Annual Community:

Species	IV	C	F	FER	P
Brassica tournefortii	F	4	13.6	**15.5**	
Erodium cicutarium	C	**4.8**	2.3	1	
Schismus	C	**65.6**	36.1	29.3	**< 0.0001**
Achyronychia cooperi	FER		0.5	**6**	
Calyptridium monandrum	F	1	**3**		
Camissonia claviformis	FER	4	3.6	**5.7**	0.3667
Camissonia pallida	F	0.9	**3**	1	
Chaenactis fremontii	FER	8.1	10.4	**13.8**	0.2416
Chorizanthe brevicornu	F	0.5	**2.4**	1.1	**0.0344**
Crassula connata	FER	0.3	**1**	0.6	
Cryptantha angustifolia	F	1.9	**5**	3	**0.0422**
Cryptantha maritima	FER			**4.5**	
Filago depressa	FER	0.3	0.2	**0.3**	
Lepidium lasiocarpum	FER	0.5		**2.4**	
Loeseliastrum schotii	F		**0.6**	0.5	
Malacothrix glabrata	F	6.3	**29.2**	26.8	
Pectocarya heterocarpa	F	0.5	**1.6**	0.5	
Pectocarya linearis	F	1.1	2.6	**3**	
Pectocarya platycarpa	F	1.3	**8.8**	1.5	
Pectocarya recurvata	FER	4.5	5.7	**11.7**	**0.0521**
Phacelia distans	C	**0.2**			

Table 1. Table of interspace and understory annual community characteristics. IV - importance value; C - control treatment; F - Fusilade treatment; FER -Fusilade and *E. cicutarium* removal; P - probability value. The treatment where a species had the highest IV score (based on relative cover and frequency) is displayed under IV. Mean % cover for each species is displayed under treatments C, F, and FER, with the highest value between treatments in bold. Probability values that are significant (P < 0.05) or very close to significant are displayed in bold among species whose % cover was statistically compared among all three treatments (C,F,and FER).

A. B.

Fig 12. **A**. Control understory habitat. **B**. Fusilade-II treated understory habitat. Dying grass appears red -brown in color.

METHODS

TREATMENTS:

Three treatments were implemented to examine the response of native vegetation to the removal of the major exotic annuals at the study site. These three treatments were:

-Removal of exotic annual grasses through use of the post-emergent, grass-specific herbicide, Fusilade II.

-Fusilade II application plus hand-weeding of *E. cicutarium*.

-Control treatment.

Designated control plots were left un-manipulated. Herbicide only and Herbicide plus weeding plots were hand sprayed with Fusilade II at the manufacturer's minimum recommended amount. Spraying took place before the grass developed seed. Hand removal of *E. cicutarium* was necessary in herbicide plus hand-weeding plots to minimize damage and/or mortality to native annuals.

EXPERIMENTAL DESIGN:

These three treatments were implemented in a randomized, complete block design that was composed of twelve blocks with three plots per block. All plots were centered on a mature *Larrea tridentata* individual (Fig 7).

SAMPLING:

Right before implementing the treatments, biomass of *Schismus* spp. and the biomass and phenology of *E. cicutarium* (as the number of individual plants in flowering and/or fruiting condition) was measured in 12 interspace samples each, using a 0.125 m^2 (50cm x 25cm) quadrat.

To document the response of the vegetation to the treatments, interspace and understory vegetation were sampled at their phenological peak biomass, which was on March 1st and 23rd, respectively. Four 0.5m^2 (100cm x 50cm) sampling quadrats were used to sample interspace and understory annual vegetation within each plot (Fig 7). Two interspace quadrats were positioned on two of the four corners of a plot, depending on which corners were best suited as interspace habitat (e.g. devoid of the influence of shrub species). The two understory quadrats were positioned directly under the canopy on the north and south side of the *L. tridentata* shrub. Data collected in the 0.5m^2 sampling quadrats included % cover by species.

Exotic and native herbaceous above-ground biomass was measured by using a 0.125 m^2 (50cm x 25cm) quadrat that was placed in the middle of the larger sampling quadrats. These data were collected twice per plot, once for understory on the north side of the creosote and once for the interspace in one of the corners of the plot.

STATISTICS:

Species richness, native biomass, and native and *Schismus* spp. % cover were analyzed with a One-way ANOVA using the PROC ANOVA command, LSD option (SAS institute, 2001). Native biomass had to be ln transformed to meet the assumptions of ANOVA before analysis. *Erodium cicutarium* and all native species with at least $n = 5$ or more in all treatments were analyzed based on their % cover data with the Kruskal Wallis test using PROC NPAR1WAY (SAS institute, 2001) to determine significant differences among treatments.

IMPORTANCE VALUE:

An importance value was generated for each species for all three treatments based on adding the relative % cover and frequency (Table 1).

RESULTS

Exotic Species Response:

Pre-treatment vs. End of Growing Season:

Interspace *E. cicutarium* biomass taken from the beginning of the experiment, when the herbicide and hand-weeding plots were treated, did not differ markedly from *E. cicutarium* biomass collected at the end of the growing season (Fig. 4). In addition, 75% of all *E. cicutarium* individuals were already flowering and/or fruiting by the January 26th treatment date.

Interspace *Schismus* spp. biomass collected on March 1st at the end of the experiment showed a large increase in biomass compared to *Schismus* spp. collected at the herbicide application dates of January 19th and 21st (Fig 4).

Treatment Effects:

Schismus spp. % cover was significantly different among treatments in interspace ($p < 0.0001$) and understory ($p < 0.0001$) micro-habitats based on one-way ANOVA. The LSD test revealed that in both micro-habitats, *Schismus* spp. cover was significantly greater in the control treatment compared to herbicide and herbicide plus hand-weeding treatments (Fig 5).

The Kruskal Wallis test showed no difference in *E. cicutarium* cover between control and herbicide treatments in interspace ($p = 0.992$) and understory ($p = 0.06$) (Fig 6.) but did show a difference when % cover was compared among all three treatments ($p < 0.0001$) (Table 1).

Native Response:

Treatment Effects:

Total native cover from both interspace and understory habitats collectively, was significantly different among all three treatments ($p < 0.0001$). Native cover was greatest in the herbicide plus hand-weeding of *E. cicutarium* treatment (Fig 8). These results were maintained when native cover was analyzed separately by both micro-habitat types (Fig. 9).

Native species richness was significantly different between control and herbicide plus hand-weeding treatments but herbicide only treatments were not significantly different from the other two treatments ($p = 0.002$) (Fig 10). Almost all native species in both understory and interspace micro-habitats had the highest importance values in herbicide or herbicide plus hand-weeding treatments. Several species from both micro-habitats had significantly ($p < 0.05$) different % cover among all three treatments (Table 1).

Native biomass was significantly greater in herbicide and herbicide plus hand-weeded treatments ($p = 0.003$) but there was no difference between the two active treatments (Fig 11).

CONCLUSIONS

The lack of difference between pre-treatment and the end of the growing season *E. cicutarium* biomass in addition to the high % of flowering and/or fruiting individuals suggests that this species reached maturity much earlier than the other annual components at this site and that the herbicide plus hand-weeding treatment may have been even more effective if were implemented at an earlier time in the growing season.

Applying herbicide before *Schismus* spp. began to flower resulted in excellent arrest of exotic grass growth and a very strong positive response of native annuals.

Native annual species had the highest % cover and species richness in herbicide and hand-weeding plots.

Application of Fusilade II at an early phenological stage for *Schismus* spp. was very effective at promoting native forb dominance. Furthermore, the dual control of the dominant exotic grass and forb species at this site resulted in the most optimal response of native annuals.

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