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EFFECT OF PARTHENIUM WEED (*Parthenium hysterophorus* L.) ON GRAZED PLANT COMMUNITIES DURING A PERIOD OF CONCERTED MANAGEMENT

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ABSTRACT

The response of a rangeland community to different parthenium weed (Parthenium hysterophorus L.) management regimes is being assessed in a pastoral area at Kilcoy, Queensland, Australia. The area selected to do this work is on a gentle slope with good drainage and has a typical soil for this region (i.e. a brown-grey Dermosol). This area has been divided into four sites to undertake the following treatments: 1) non-grazed with chemical control applied; 2) non-grazed without chemical control; 3) grazed with chemical control applied and 4) grazed without chemical control. In the previous season, prior to the application of these treatments (i.e. in summer 2009/2010) the species composition of the community was recorded and used as the community benchmark. This paper reports upon that community structure. In total, 48 plant species were recorded within the above-ground community and 64 species within the soil seed bank. The above-ground vegetation was dominated by stoloniferous grass species, but there was also a high frequency of species belonging to the Malvaceae, Chenopodiaceae and Amaranthaceae families. Parthenium weed was found in high abundance and frequency within all of the four sites (i.e. 100 % and 63 % respectively). A correlation analysis showed that parthenium weed frequency was negatively associated with the Shannon index, as well as with the dry matter of the remaining species. A similar trend was found within the soil seed bank, with the species diversity being lower when parthenium weed's frequency was higher. These preliminary results provide a background against which the effect of chemical management of parthenium weed and/or a reduction in grazing pressure might improve the species composition of the community, which will be best seen in the years to come.

Keywords: Parthenium weed, seed bank, grazing management, chemical control.

INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L.) is thought to significantly influence both the diversity and productivity of grassland

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plant communities (Adkins and Navie, 2006; Evans, 1997; Navie *et al*., 2004; Nguyen *et al.,* 2010; Nigatu *et al*., 2010; Olff and Ritchie, 1998). Currently in Australia, parthenium weed is mostly a grassland weed, affecting cattle production in up to 20 million hectares of Queensland (Adkins, 2010, personal communication; Bostock and Holland, 2010). Previous studies on parthenium weed and its effect on plant biodiversity have reported a total habitat alteration and rapid replacement of native grasses and other herbaceous species that were valuable grazing plants (Evans, 1997), a reduction in the diversity of other plant species as well as their seed banks (Navie *et al*., 2004) and the replacement of native vegetation in several ecosystems (Yaduraju *et al*., 2005). The replacement of native species usually leads to a loss in the quality of the grazing land as less palatable species colonize. This in turn, reduces herbage palatability and digestibility leading to a lowering of the carrying capacity of the grassland. As rangelands in Queensland cover more than 70% of the total state area, representing about 49% of the national cattle production, parthenium weed causes a serious threat to domestic stock yields and native plant community biodiversity.

The response of plant communities to livestock grazing differs across environments, especially when other factors such as the presence of an invasive species, are considered. An increase in community biodiversity, as a consequence of grazing, is often observed when domesticated large grazers are managed at low stocking rates on productive grasslands (Petraitis *et al.,* 1989). While other studies have shown that grazing has a slight or negative impact upon biodiversity (Kelt and Valone, 1995). In general, it has been found that diverse communities (i.e. those with high species richness) are more resistant to invasion (Richardson and Pysek, 2006). Therefore, grasslands with a long history of grazing cattle usually present low resistance to invasion by an aggressive weed species such as parthenium weed. Uptil now, little has been reported about the changes in species richness within a plant community when grazing is reduced and/or the invasive species are managed. In addition, very little has been reported concerning this topic when parthenium weed is the invasive species (Nguyen *et al.,* 2010).

The aim of the present study is to characterize, then determine the response of a rangeland community to different parthenium weed management and grazing strategies, both when assessed in the above-ground and in the below-ground communities. This will provide an insight into the effect of parthenium weed upon the species composition and richness of these plant communities which can then be used to determine the speed of recovery of the community once the weed is removed and/or the grazing rate is reduced.

MATERIALS AND METHODS

Study location

This investigation was conducted at a property located in the Kilcoy district (27.11° S, 152.56° E) in South-East Queensland, Australia. The altitude of the site ranged from 225 to 238 m above sea level. The site has a gentle slope with good drainage and a typical soil of the region (i.e. brown-grey Dermosol, pH 6). The characteristic vegetation of the region was that of a native grassland but under continuous grazing, this has led to the replacement of certain desirable native species, such as black speargrass (*Heteropogon contortus* L.), with other less desirable species (Loi and Malcom 1998). The site has also been infested by parthenium weed for at least 25 years (Youles 2011, personal communication). Surveys were undertaken in the summer of 2009/2010 (i.e. February 2010) and the winter of 2010 (i.e. August 2010). Before and during these studies, the land was grazed by cattle at a typical stocking rate of *ca.* 0.5 cows ha^{-1} during the drier winter months to 0.8 cows ha^{-1} (Youles 2011 personal communication). For the past few years, the land was also subjected to an annual aerial application of mixture of Brush-Off ® at 10g/100 L water and 2,4-D at 320mL/100 L for the management of parthenium weed, except for 2009 when a shortage of rainfall meant that there was no need to undertake this management program (Lampard, 2011, personal communication). The climate of the site is characterized by sub-tropical conditions, with a 40 year average annual precipitation of 950 mm occurring mainly in the summer (i.e. January and February). However, the annual rainfall was well above average during the surveyed year (i.e. 1619 mm for 2010). The mean night time temperatures are lower than 7°C in the winter nights and above 29°C during the day in the summer (Australian Bureau of Meteorology, 2011).

Within this location, two rectangular plots (*ca.* 300 m^2) were selected; both with similar densities of parthenium weed infestation. One plot was protected by erecting a fence so no cattle or wild life could graze the land for the duration of the study (i.e. February 2010 to February 2012). The other site continued to be subjected to grazing (*ca.* stocking rate of 0.5 cows ha^{-1} during the drier winter months to 0.8 cows ha^{-1}). Within each plot, two equally sized sub plots were defined: one having a herbicide application (i.e. mixture of Brush-Off ® at 10g/100 L water and 2,4-D at 320mL/100 L) applied twice a year in autumn, and the other two sub plots without any herbicide application. This created four treatments: 1) non-grazed with chemical weed control applied; 2) non-grazed without chemical weed control; 3) grazed with chemical weed control applied and 4) grazed without chemical weed control.

In the previous season, and prior to the application of the treatments (i.e. in summer 2009/2010), the species composition of the community was assessed for each sub plot. This community analysis will be used as the benchmark for all future community comparisons. The response of plant communities to each treatment over time will be determined with subsequent assessments on the site using the same sampling methodology.

Assessment of the above-ground species diversity

The above-ground vegetation was determined through sampling using 40 quadrats (1 m^2; 10 for each treatment). Within each quadrat, the above-ground plant community composition and species density of all species were determined by counting the number of individual species present. If plants were at the edge of a quadrat, only those rooted within the quadrat were counted. However, the density of two stoloniferous species: blue couch (*Digitaria didactyla* Willd.) and green couch (*Cynodon dactylon* (L.) Pers.) were estimated in the field by a coverage method which involved a visual estimate of the proportion of the quadrat occupied by these two species (Smart *et al*. 2006). Therefore, a conversion to individual plants was necessary for data analysis. It was assumed that each 2% of cover corresponded to an individual (i.e. 50% of coverage = 25 individuals). The determination of the above-ground biomass was taken from only a quarter of the quadrats (i.e. 0.25 m^2) and divided into parthenium weed and all other species (i.e. forbs, legumes, grasses and weeds). Upon cutting, these two classes of plants were put into separate brown paper bags and, upon returning to the University of Queensland, dried in an oven at 90 ± 5 °C for *ca.* 72 hours.

Assessment of the soil seed bank

To assess the soil seed bank in the four plots, two soil cores were collected from each of the 40 quadrats with a metal soil corer which has a diameter of 10 cm and could sample to a depth of 15 cm. The cores remained intact when removed from the soil and the two samples from each quadrat were mixed together. Hence, a total of 10 soil seed bank samples were collected from each plot during each survey season. The soil samples collected in the field were then spread thinly (5-7 mm layer) over a sterilized soil (University of California mixture; 3 cm thick layer) that was contained within a shallow plastic tray (20 × 25 × 6 cm, w/l/h; one quadrat per tray). These trays were distributed randomly on benches within a glasshouse at the University of Queensland, Brisbane, with a temperature maintained as close as to the ambient temperature outside using exhaust fans and an evaporative wet wall cooling system. Two control trays of sterilized soil alone were placed among the experimental trays to monitor for any seedlings that may have arisen from the soil or from the glasshouse environment. All trays were watered daily to maintain soil moisture content approximately at field capacity. Trays were observed weekly for any newly emerging seedlings. Once they had emerged, seedlings were counted and removed as soon as possible, depending on identification complexity. In the case where easy identification was not possible, representative individuals were planted into small pots and grown to maturity, to allow for later taxonomic identification. When no further emergence was recorded, the soil was stirred and watering stopped for a week, then rewatered to trigger further germination. Each seed bank assessment, from every survey season, was run over a six month period to allow for all of the species in the seed bank to be identified, including those with long-term seed dormancy. The 'unidentified species' term was used for several seedlings that died before they could be identified.

Statistical analysis

The data collected was used to characterize the vegetation composition using the following parameters calculated for individual species using the following formulae:

1) Presence of species A (%) $= \frac{\text{Number of sub-plots where species A occurs}}{\text{Total number of sub plots}} \times 100$
2) Frequency of species A (%) $= \frac{\text{Number of quadrats where species A occurs}}{\text{Total number of quadrats sampled}} \times 100$
3) Density of species A $= \frac{\text{Number of individuals of species A}}{\text{Total number of quadrats where the species A occurs}}$

The species diversity within the above-ground vegetation and the seed bank was assessed using the Shannon-Weiner index ($H' = -\sum^{S}_{i=1} p_i \log_e p_i$, where S is the number of species or species richness, N is the total number of all individuals and p_i is the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community:

$$p_i = n_i / N,$$

Where, n_i is the number of individuals in species $_i$ i.e. the abundance of species $_i$ (Krebs, 1989). All data sets were analysed by an Analysis of Variance using a General Linear Model procedure in Minitab, version 16 (Minitab Inc., USA). No data transformation was needed. The general linear model was set up with two seasons (summer and winter) and two grazing and herbicide treatments as factors for the analysis of the Shannon index and species density data. They were analysed using an Adjusted Sum of Squares approach using 95.0 % confidence intervals. A correlation analysis was used to study linear associations between the measured variables and the calculated parameters.

RESULTS

Above-ground species diversity

In total, 48 species were recorded in the above-ground plant community and 64 species in the soil seed bank prior to the application of the treatments (Table-1). In the above-ground community, 12 species belonged to the Poaceae, three to the Asteraceae and the remaining 37 species came from 16 other families. Native species represented 48% of those present in the above-ground plant community. The remainder were introduced weed species, most of which were broadleaf species (18 species). The majority of the species identified in the above-ground community were perennials and/or annuals that could behave as perennials depending on weather conditions (45.8 and 22.9 % respectively).

The most dominant species in the above ground plant community were the weed species *Portulaca oleracea* L. (100 and 85%, respectively) and *Dysphania carinata* (R.Br.) Mosyakin & Clemants (100 and 70% respectively) and the grass species *Digitaria didactyla* Willd. (100 and 78%, respectively) and *Paspalidium distans* Trin. (100 and 68% respectively). The presence, frequency and density of parthenium weed were high to moderate across the whole site (i.e. 100%, 62.5%, 5.69 plants m^{-2} respectively). The dry matter of all other species in the quadrat was negatively correlated to the dry matter (r^2 = -0.35; P = 0.029), density (r^2 = -0.56; P = 0.001) and frequency (r^2 = -0.44; P = 0.05) of parthenium weed. However, the Shannon-Wiener index was not significantly correlated to the frequency, density or dry matter of parthenium weed.

Table-1. The presence, frequency and density of plants in the above-ground or seeds in the below-ground plant community at a pastoral site in Kilcoy during the summer of 2009/2010.

Species	Presence (%)		Frequency (%)		Density (m^{-2})	
	Above-ground	Below-ground	Above-ground	Below-ground	Above-ground	Below-ground
Alternanthera nana	25	25	5.0	5.0	0.05	1.03
Alternanthera pungens	100	25	45.0	10.0	1.10	4.13
Amaranthus spinosus	25	50	2.5	2.5	0.03	7.23
Amaranthus viridis L.	0	25	0.0	2.5	0.00	1.03
Anagallis arvensis L.	0	25	0.0	2.5	0.00	1.03
Aristida sp.	50	0	5.0	0.0	0.08	0.00
Boerhavia dominii	25	0	2.5	0.0	0.03	0.00
Bothriochloa decipiens	100	75	57.5	7.5	2.23	0.00
Chloris divaricata R.Br.	75	100	12.5	27.5	0.18	23.77
Chloris ventricosa	0	25	0.0	7.5	0.00	8.27
Conyza bonariensis	0	100	0.0	37.5	0.00	63.06

Species	Presence (%)		Frequency (%)		Density (m^{-2})	
	Above-ground	**Below-ground**	**Above-ground**	**Below-ground**	**Above-ground**	**Below-ground**
Conyza sumatrensis	50	75	7.5	17.5	0.15	17.57
Crassula sieberiana	0	75	0.0	7.5	0.00	3.10
Cyclospermum	0	75	0.0	20.0	0.00	12.40
Cynodon dactylon (L.)	50	50	17.5	5.0	0.99	4.13
Cyperus brevifolius	0	100	0.0	30.0	0.00	28.94
Cyperus gracilis R.Br.	100	100	55.0	97.5	1.28	1515.7
Cyperus iria L.	0	50	0.0	10.0	0.00	5.17
Datura ferox L.	25	0	2.5	0.0	0.05	0.00
Digitaria didactyla	100	100	77.5	90.0	14.20	625.51
Dysphania carinata	100	100	70.0	50.0	3.20	107.52
Dysphania pumilio	0	100	0.0	70.0	0.00	200.57
Einadia polygonoides	75	100	20.0	72.5	0.20	122.00
Einadia trigonos	100	100	20.0	45.0	0.40	46.52
Eleusine indica (L.)	50	75	22.5	22.5	0.33	18.61
Eragrostis cilianensis	25	100	2.5	32.5	0.03	16.54
Galactia tenuiflora	75	0	17.5	0.0	0.25	0.00
Gamochaeta	0	75	0.0	32.5	0.00	42.39
Glycine sp.	75	0	22.5	0.0	0.33	0.00
Gomphrena	75	25	12.5	5.0	0.18	2.07
Heliotropium	0	50	0.0	5.0	0.00	6.20
Hydrocotyle acutiloba	0	50	0.0	27.5	0.00	18.61
Ipomoea sp.	25	0	2.5	0.0	0.03	0.00
Juncus usitatus	0	25	0.0	5.0	0.00	2.07
Lepidium africanum	75	100	15	37.5	0.23	80.64
Lepidium bonariense	0	100	0.0	45.0	0.00	34.12
Lepidium didymum L.	0	100	0.0	57.5	0.00	172.66
Macroptilium	25	0	2.5	0.0	0.03	0.00
Malva parviflora L.	50	25	5.0	5.0	0.08	2.07
Malvastrum	25	75	2.5	10.0	0.03	5.17
Malvastrum	100	25	25.0	2.5	0.40	1.03
Ophioglossum	50	0	5.0	0.0	0.13	0.00
Oxalis exilis A. Cunn.	100	100	50.0	95.0	0.95	687.55
Oxalis purpurea L.	50	100	7.5	57.5	0.13	139.58
Parthenium	**100**	**100**	**62.5**	**67.5**	**6.33**	**1298.5**
Paspalidium distans	100	100	67.5	60.0	3.83	89.95
Plantago debilis R.Br.	75	100	7.5	25.0	0.10	17.58
Polygonum aviculare	0	25	0.0	2.5	0.00	1.03
Portulaca oleracea L.	100	100	85.0	95.0	3.43	911.91
Portulaca pilosa L.	50	100	5.0	37.5	0.05	33.09
Pterocaulon redolens	0	50	0.0	5.0	0.00	2.07
Rumex brownii	75	50	15.0	12.5	0.15	12.41
Schenkia spicata (L.)	0	100	0.0	87.5	0.00	385.64
Sida cordifolia L.	50	25	5.0	2.5	0.05	2.07
Sida rhombifolia L.	100	50	32.5	7.5	0.50	3.10

Species	Presence (%)		Frequency (%)		Density (m^{-2})	
	Above-ground	Below-ground	Above-ground	Below-ground	Above-ground	Below-ground
Sida spinosa L.	100	75	37.5	17.5	0.53	12.41
Sida subspicata	100	0	50.0	0.0	2.58	0.00
Sisyrinchium sp.	0	25	0.0	2.5	0.00	2.07
*Solanum americanu*m	75	50	30.0	5.0	0.65	2.07
Soliva sp.	0	50	0.0	17.5	0.00	369.11
Sonchus oleraceus L.	0	25	0.0	5.0	0.00	2.07
Sporobolus creber De	25	100	2.5	32.5	0.03	63.07
Sporobolus elongatus	25	75	2.5	27.5	0.03	32.05
Stachys arvensis (L.)	0	25	0.0	2.5	0.00	1.03
Tribulus micrococcus	100	0	45.0	0.0	1.10	0.00
Urochloa panicoides	25	25	2.5	2.5	0.03	2.07
Urtica incisa Poir.	0	25	0.0	2.5	0.00	1.03
Verbena litoralis	25	50	2.5	7.5	0.03	5.17
Verbena rigida	25	75	2.5	20.0	0.08	11.37
Vittadinia sulcata	0	25	0.0	2.5	0.00	1.03
Wahlenbergia gracilis	0	100	0.0	67.5	0.00	111.66
Unknown 1(shrub)	75	0	42.5	0.0	1.30	0.00
Unknown 2	0	75	0.0	10.0	0.00	4.14
Unknown 3	0	25	0.0	2.5	0.00	1.03
Unknown 4	0	25	0.0	2.5	0.00	2.07

Soil seed bank diversity

The seed bank analysis showed a slightly more diverse flora than was seen in the above-ground vegetation (average Shannon-Wiener index: 2.2 and 1.8 respectively), with an additional 11 botanical families represented there. Similar to the above-ground plant community, the seed bank had 12 species belonging to the Poaceae, however there were eight species belonging to the Asteraceae and 44 species from 25 other families. Native species represented only 39% of those present in the below-ground community. The remainder were introduced species, and 88.2% of these were considered to be pasture weeds. The seed bank correlation analysis did not show the same significant negative trends as the above-ground results.

DISCUSSION

At the start of the study, the above-ground plant community was clearly dominated by species considered to be weeds (i.e. 38 weed species with only 12 grass species present). Only three grasses showed 100% presence (*i.e. Digitaria didactyla* Willd.*, Paspalidium distans* (Trin.) Hughes and *Bothriochloa decipiens* (Hack.) C.E.Hubb.). According to previous observations of the region's native pastures by Loi and Malcom (1998), this kind of plant community composition was indicative of a history of heavy grazing. Thus, this community probably presents a low resistance to invasion by weeds, including parthenium weed and may explain why there is a high presence and frequency of the weed at the site.

Although the frequency and presence of the dominant species recorded in the survey changed in magnitude for the seed bank, *Portulaca oleracea* L., *Digitaria didactyla* Willd, *Dysphania carinata* (R.Br.) Mosyakin & Clemants, *Paspalidium distans* (Trin.) Hughes, *Parthenium hysterophorus* L., *Cyperus gracilis* R.Br. and *Oxalis exilis* A. Cunn. were still the most common species (Table-1).

Conversely to what has been reported before (Nguyen *et al.,* 2010; Nigatu *et al*., 2010) the plant diversity, either in the above or in the below ground community did not show a decrease under high frequencies of parthenium weed. However, greater biomass of the weed did show a negative effect on the community's biomass production.

The greater number of species and families found in the below-ground community, and the lack of negative correlations with parthenium weed frequency and density at the seedling stage, may indicate that it will be possible to recover this grassland community once the invader is better managed. Further data collection over the coming year will show if there is any recovery of the biodiversity and biomass production of the community due to the chemical control of parthenium weed and which functional groups (i.e. forbs, weeds, and woody species) prosper after the application of the treatments.

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