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Weed seed bank as affected by crop rotation and disturbance

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ABSTRACT

An experiment was conducted to determine the influence of crop rotations on soil seed bank to provide a comparison between crop fields and non-crop lands. Crop rotations were continuous dryland wheat (Wd), continuous irrigated wheat (Wi), wheat-sugarbeet (WS) and wheat-chickpea (WCh). Nearby pastures (P) and orchards (Or) were also studied for comparison purposes. Estimates of the density of seed banks ranged from 52779 seed m^{-2} in P to 9906 seeds m^{-2} in Wd. A total of 114 plant species from 24 families were identified from seeds collected from different farms. 33 weed species were at high frequency in weed communities. Crop rotations were dominated by annual weed species, while the weed species dominated in P were mostly not found in any crop rotation. The two weed species *Roemeria refracta* and *Eragrostis cilianensis* were frequently present in all the study sites. *Amaranthus chlorostachys* and *Euphorbia esula* were more abundant in the areas of moderate to high disturbance. In SW and WS rotations, due to use of grass herbicides and hand weeding, winter annual broadleaves such as *Lactuca serriola* and *Anchusa italica* were the prominent species in the seed bank. Results showed that a number of weed species are adapted to a specific crop sequences and disturbance levels. Weed species richness, seed bank abundance and diversity in soil depths are highly dependent on disturbance levels. The current study highlights the importance of agricultural practices including crop sequences or disturbance levels in determining the characteristics of weed populations. This provides useful information to improve methods for maintaining plant population balance.

1. Introduction

Weeds reduce both the quantity and quality of crop. Current weed control programs have mainly focused on chemicals leading to rapid evolution of herbicide-resistant weeds and serious environmental concerns. Therefore, integrated methods are being widely considered by researchers. Successful integrated approaches require deep understanding of the weeds biology and ecology. Weed seed bank in soil as source of weed population is a subject of importance for weed ecologists. A soil seed bank includes all viable seeds and vegetative propagules present on and in the soil which might be originated from the recent seed rain or previous years (Shrestha et al., 2002). Thus, the soil seed bank can also reflect a history of weed populations existed in the past (Cavers, 1995). Knowledge about the size and composition of seed bank provides insights into the processes of weed community transitions that are used for predicting the occurrence of exotic species, and suggesting sustainable weed control methods (Abella and Springer, 2008). Wilson reported that although, many weed species exist in seed banks, 70–90% of the total seed bank belongs to a few dominant species (Wilson, 1988). Soil seed bank population is significantly influenced by crop rotation (Ball, 1992) and tillage type (Blackshaw et al., 2001). However, crop rotation is a more influential than any other practices (Cardina et al., 2002). Even after two years of crop sequences, important changes were caused in weed populations (Bellinder et al., 2004). For instance, a two year crop rotation of barley-vetch showed a greater abundance, and diversity of weeds than the barley-sunflower sequence or continuous barley (Dorado et al., 1999). The lower plant height of vetch and enhancement in the soil fertility (especially N) obtained from a legume crop (vetch) in the rotation were among the reasons for higher weed population in the mentioned crop rotation. Ball (1992) found that in a 3-year continuous pinto bean, the broadleaf weeds became dominant. Their result also showed that a crop sequence of two years sugarbeet followed by corn in the third year caused different dominant species.

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Inclusion of small grains in rotations has also been decreasing in weed infestations (Schreiber, 1992; Liebman and Dyck, 1993). Allelopathy and the increased exposure to predators and pathogens are mentioned among reasons for this effect.

Species composition of weed communities is affected by the patterns of disturbance in agricultural ecosystems. Crop rotations bring diversity in the type and timing of soil, crop, and weed management tactics. Crop rotations create higher possibility for weed mortality compared to monoculture (Martin and Felton, 1993). On the other hand, variation in crop sequences can also increase weed emergence, establishment and seed production (Dorado et al., 1999). Understanding the influence of crop rotations and their companion impacts on weed seed bank provides helpful information to improve decision making systems (Ball, 1992). The objective of this study was to determine the influence of crop rotations on seed bank size and composition and to provide a comparison between crop fields and non-crop lands (pasture) in the Kurdistan province (North West of Iran).

2. Materials and methods

The present study was carried out in autumn 2011 at arable fields, orchards and pasture lands located in northwest of Saqqez county, Kurdistan Province, Iran (36°14′N, 46°17′E with altitude of 1420 m above sea level). The mean annual precipitation at the location is 400 mm and the absolute maximum and minimum temperature is +42° C and −32° C, respectively. Average distance between Wd fields was 10 km (±2.6) and for Wi, Ws, Sw. WCh and ChW was 4 (±3.4), 3 (±3), 3 (±1), 10 (±5) and 10 (±4.3) km respectively. Pastures were around and orchards were between the field crops.

The characteristics of study fields are described in Table 1.

Questionnaires were filled by farmers requesting information about history of cultural practices in fields were the basis for study fields selection (Table 2).

Irrigated wheat, dryland wheat and chickpea were hand planted in rows spaced by 17, 25 and 40 cm apart, respectively. Prior to wheat planting, full recommended rate of fertilizer Phosphorus +50% rate of recommended nitrogen fertilizer were incorporated into the soil by disk-harrowing. Sugarbeet was machinery planted in rows spaced by 50 cm apart. Full recommended rate of phosphorus and potassium fertilizers +30% rate of the recommended nitrogen were incorporated into the soil prior to sugarbeet planting. The rest of nitrogen fertilizer was applied as top-dressed during the wheat tillering stage and sugarbeet 6–8 leaf stage.

Weed seed banks were sampled prior to crop planting (October 27 to November 12). Sampling sites were arranged in a W pattern across the fields, and the samples were taken from soil depths of 0–5 cm, 5–15 cm and 15–25 cm by auger (a volume of 100 m^{-3}). Based on the field size (1–3 ha), 7 − 11 samples were taken from the study fields. . Compound sampling (four samples from radius of one meter) was taken for every sample; samples of each depth were then mixed together and a 100 cm^3 from each depth were put into nylon bags and stored in a cool dry place.

Weed seeds were separated using cloth bag method (Mesgaran et al., 2007) which is briefly described: 10 by 15 cm fine net cloth bags (65-mesh) were used. Samples were poured into the bags and manually washed under running tap water to retain weed seeds that were gravel incorporated. The residues were put in the plastic dishes and then air-dried at room temperature to be enumerated under a binocular microscope.

Only the seeds that were resistant to the gentle pressure of forceps were considered viable and counted (Forcella, 1998). Weed species were visually identified using reference books and atlases of seed using the Carretero method (Dorado et al., 1999). Seeds that could not be identified using the mentioned method were grown in trays and their seedlings were identified using Flora of Iran (Ghahreman, 1978–2006). The seeds that were neither germinated nor identified were classified as unknown seeds. Each species was classified into functional groups by their life cycle and morphotype (Table 3).

As data had normal distribution, no data transformation was required. Analysis of variance (ANOVA) was performed on the data using the PROC GLM procedure of SAS (SAS 9.1, 2003). Weed species that rarely existed among rotations (frequency < 3) were not included in the analysis.

The overall variation patterns in the species composition across fields were recognized with principal components analysis (PCA) (using PROC PRINCOMP in SAS).

Shannon's diversity index and species richness were used as the measures of species diversity. The number of plant species in the field was considered as the level of species richness (Kent and Coker, 1992). Shannon's diversity index for each field was estimated as follows (Kent and Coker, 1992):

$$H = \sum_{i=1}^{s} \left(\frac{n_i}{N}\right) \left(\log_2 \frac{n_i}{N}\right)$$

where N is the total number of individuals per field, n_i refers the number of individuals per species per field and S describes total number of species.

The evenness of species in each crop rotation was also calculated using the Shannon's diversity index as follows (Kent and Coker, 1992):

$$J = \frac{H}{\ln(s)}$$

Table 1
Description of the fields samples in the study.

Treatment	Crop in the year of sampling	Number of year in this rotation	Number of fields sampled
Wd	Wheat	9	3
Wi	Wheat	5	3
WS	Wheat	6	3
SW	Sugar beet	6	3
WCh	Wheat	5	3
ChW	Chick	5	3
Or	–	12	4
P	–	–	3

Wd-continuous cropping of dryland wheat; Wi-continuous cropping of irrigated wheat; WS-wheat/sugarbeet rotation; SW-sugarbeet/wheat rotation; WCh-wheat/chickpea rotation; ChW-chickpea/wheat rotation; Or-orchard; P-pasture.

3. Results and discussion

3.1. Seed bank composition and abundance

A total of 114 plant species from 24 families were identified from seeds collected from different farms, among which 33 weed species were at high frequency in weed communities (Table 3). Pasture and orchard although not being statistically different in the number of weed species, showed significant difference from other crop rotations in weed species number observed in depth of 0–5 cm. On other hand, there was no significant difference between the other rotations. Comparing the species number in two depths 5–15 or 15–25 showed no difference between crop rotations, pasture or orchard (Fig. 1). Results indicated that the two weed species