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Soil seed bank and seedling populations of *Hordeum murinum* and *Cardaria draba* in saffron fields

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Abstract

Geostatistical techniques were used to characterize the spatial relationship between *Hordeum murinum* and *Cardaria draba* seedling and soil seed bank over the entire growing season of 2004–2005 in three saffron (*Crocus sativus*) fields, located in Southern Khorasan (33°N latitude, 57°E longitude), Iran. The maps of *H. murinum* seed bank density corresponded moderately to those seedling density in a and strongly to those in b and c fields. The emergence percentage of *C. draba* was higher than for *H. murinum* in all fields. Semivariograms showed spatial autocorrelation in seed bank and seedling populations of *H. murinum* and *C. draba* in all fields. Grey-scale field maps of *C. draba* seed banks corresponded visually to maps of seedling populations and could have been used to target control efforts, but visual correspondence between *H. murinum* seed bank and seedling maps was poor.

Keywords: Weeds map; Geostatistics; Spatial dependence; Spatial pattern; Saffron

1. Introduction

Understanding the spatial and temporal dynamics of weed populations and the rate of their spread within fields is increasingly important as methods are being developed for the site-specific management of weeds (Zhang et al., 2002). Several studies have shown that weeds are not randomly distributed but are aggregated at one or more spatial scales (Cardina et al., 1995; González-Andújar and Saavedra, 2003; Jurado-Expósito et al., 2004). Stability is important from the perspective of patch management, so that a patch map from 1 year can be used to direct weed control in subsequent years (Mortensen et al., 1998). Knowledge of spatial variability helps to improve weed management efficiency (Wiles et al., 1992; Colbach et al., 2000). Currently, yield loss is usually overestimated (Brain and Cousens, 1990) as patchiness of weeds may result in incorrect evaluation of control measures (Wiles et al., 1992). Previous approaches to determine the relationship between weed seed bank populations in soil and future seedling populations have generally relied on correlation coefficients and regression techniques to generate single values describing relationships between global means and variances (Forcella, 1992). If seed bank data are to be valuable in characterizing and predicting weed populations for weed management, they should describe the spatial distribution of weeds in a field. Weed threshold densities are generally low, and densities of weeds within a patch commonly exceed threshold levels (Cardina et al., 1996). Therefore, seed bank data may be more valuable if they describe the pattern of the weed population than if they simply predict a single density value for a field. Information about the spatial pattern of weeds in a field could be used to target control efforts as well as to develop efficient scouting protocols. The cross-semivariogram analysis of spatial statistics is one way to describe the variation between seed bank and emerged populations in a field. Cross-semivariograms describe the joint spatial dependence, or continuity, between two variables such as the seed bank and emerged weeds. This approach has been used to examine the spatial relationship between two soil properties (Vauclin et al., 1983), two

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carabid species, summer and fall collections of the same insect (Rossi et al., 1992), and other pairs of variables that are influenced by the same local conditions or spatial processes (Trangmar et al., 1985). The objective of this study was to describe the spatial relationship between fall populations of seeds in the soil seed bank and winter populations of seedlings in three saffron (*Crocus sativus* L.) fields.

2. Materials and methods

Field experiments were conducted during the growing season of 2004–2005 in three fields (a, b, and c separated about 150 m from each other) 32 m wide and 60 m long, located at Boshrooyeh region in southern Khorasan, Iran. The soil was sandy loam and the fields were fertilized with 250 kg ha^{-1} ammonium phosphate according to soil tests recommendations every year. Saffron had been sown in late August of 2002. Haloxyfop-*R*-methyl (Galant super) (c) was applied to the three fields at a rate of 162 g.a.i ha^{-1} during the first week of every year, to control winter annual grasses. Weeds were also counted after each herbicide application. *H. murinum* (L.) Huds. subsp. *gussoneanum* (mouse barley as a winter annual grass) and *C. draba* (L.) Desv. subsp. c*halepensis* (hoary cress) as a perennial weed are the most important weeds monitored in saffron fields in Iran (Rashed, 1992). *H. murinum* and *C. draba* seedling and seed bank density assessments were performed following a 4 m × 4 m grid pattern on each area, a total of 144 sampling units on each field. At each node of grid pattern, the numbers of weed seedlings were counted in the three fields within a permanent 50 cm by 30 cm quadrat, perpendicular to crop rows. During the fourth week of January 2005, the edge of the quadrat was placed about 1 cm from the edge of the hole left by the soil probe so that the seed bank extraction and the seedling counts were as close as possible.

In early November 2004, soil samples were taken with an auger 5 cm in diameter and 7.5 cm deep. A total of 144 cores were collected from each node of grid pattern. Each core was analyzed individually. Soil from each core was mixed with 250 ml 0.5% sodium hexametaphosphate (Calgon solution). The suspension was passed through two sieves. The upper one with 0.5 mm mesh size and the lower one with 0.2 mm mesh size. The hollow seeds floating on the surface of the suspension were discarded. Subsequently, the material retained on the lower sieve was collected on a piece of filter paper and air-dried. Seeds were counted and identified by species under a stereomicroscope (10×). Viability test was not performed and thus the viability cannot be assured.

2.1. Geostatistical analysis

The seed bank and seedling data at each sampling site were converted to ground area unit. Percentage emergence was calculated as the density of emerged seedlings (from quadrat counts in the field) divided by the density of seeds in the seed bank (from corresponding soil core samples). Before subjecting data to spatial statistical analysis, they were log-transformed and detrended by a median polishing procedure as described previously (Cardina et al., 1995). The semivariance statistic was calculated as half the average squared difference between data values at pairs of points a given distance apart (Rossi et al., 1992). To describe the spatial correlation between data points the semivariance statistic was calculated as:

$$\gamma\left(h\right) = \frac{1}{2N(h)}\sum_{i=1}^{N(h)}\left[Z(X_i) - Z(X_i + h)\right]^2 \tag{1}$$

where $\gamma(h)$ is the empirical semivariance for the distance h, $N(h)$ the number of points separated by the distance h, and $Z(X_i)$ is the weed density at location X_i. This statistic was then plotted against the separation distance h, yielding the empirical semivariogram, which characterizes the spatial variability of weed densities as a function of distance between locations (Colbach et al., 2000). Empirical semivariograms were calculated for seed bank and seedling population data using GS+ software (Anonymous, 1994). To describe the co-continuity of two variables (seed bank and seedling populations) cross-semivariance was calculated as:

$$\gamma_{AB}(h) = \frac{1}{2N(h)}\sum_{i=1}^{N(h)}(Z_A(X_i) - Z_A(X_i + h) \times Z_B(X_i) - Z_B(X_i + h))] \tag{2}$$

where $\gamma_{AB}(h)$ is the cross-semivariance for sample sites separated by distance h. $Z_A(X_i)$ and $Z_B(X_i)$ are the attributes of two variables (seeds and seedlings here) and X_i and $X_i + h$ represent any pair of locations separated by a distance h. $N(h)$ is the number of pairs of sample sites separated by distance h. Cross-semivariograms were used to calculate the value of $\gamma_{AB}(h)$. Semivariograms and cross-semivariograms were calculated both isotropically and anisotropically using GS+ and Variowin (Software for spatial data analysis in 2D, Spring Verlag, New York, USA) (Pannatier, 1997) softwares, respectively. The computations were performed in four directions (0°, 45°, 90°, and 135°, counterclockwise from the East-West direction, as crop rows direction) with an angular tolerance of 22.5° to determine whether the semivariogram and the cross-semivariogram functions depended on direction (i.e. they were anisotropic or isotropic). For all semivariograms and cross-semivariograms the number of distance classes was 8, with a distance between classes set at 4 m. The lag tolerance was as default, direction = 0° and angular tolerance = 90°, maximum bandwidth = no limits. Each point on all graphs represents data for a minimum of 720 pairs of sample sites. Log normal transformed data were used to fit semivariograms. Comparison of different models parameters were used to