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Charaterising Spatial Weed Distribution with a Distance Index of Dispersion and the Effect of Spatial Scales

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Abstract: A distance index of dispersion (Johnson and Zimmer's Index, *I*) was used to describe the spatial distribution of five species of weeds (*Polygonum aviculare, Papaver rhoeas, Descurainia sophia, Lolium rigidum and Anacyclus clavatus*) growing in vetch crop. Three spatial scales, a large area of 9.0×4.5 m, a medium area of 3.0×1.5 m and a small area of 1.0× 0.5 m, were considered. At the three spatial scales examined, the five weed species did not present a significance departure from the random distribution. The Johnson and Zimmer's Index, *I*, showed a robust behaviour across scales.

Keywords: Johnson and Zimmer's index · *Polygonum aviculare* · *Papaver rhoeas* · *Descurainia sophia* · *Lolium rigidum* · *Anacyclus clavatus* · random distribution

INTRODUCTION

The importance of spatial distribution in sampling weed populations, modelling population dynamics and long-term weed management, has drawn attention to the need for methods to describe and analyse the spatial distribution of weeds. The tacit assumption of the random distribution of weeds through the crop is the foundation of the most important weed models and management strategies [1, 2]. These assumption leads to the overestimation or underestimation of crop yield if the weed spatial pattern is not random distributed. Thus, some researchers [3, 4] concluded that for patchy distribution of weeds, crop yield will be underestimated and so the overestimation of yield loss. Also, this could have an unnecessary and costly herbicide use in same places of the field [5]. Knowledge of spatial variability is also essential if the potential benefits of improved understanding of weed control are to be achieved [6, 7].

Previous attempts to describe spatial weed distribution have used dispersion indices (variance-to-media ratio, Morisita's index, etc.) and statistical distributions (negative binomial distribution, Taylor power law, etc.) [8-11]. However, they neglect the location, separation and two-dimensional distribution of weeds and cannot be used to estimate density, location, or arrangement of weeds in agricultural fields [12]. Therefore, alternative methods that rely on the geographic location on samples must be used to draw accurate information about spatial arrangement. Distance indices offer such alternative approach.

Distance indices are based on individual-to-individual and point-to-individual distances and has a long tradition in ecology [13]. Many different distance indices of dispersion has been proposed in the literature to detect non-randomness in animal and plant populations [14]. However, until recently they had not been applied in weed science [15]. Many distance indices have been shown to have various limitations [16]. For example, Pielou's index requires an independent assessment of population density. Johnson and Zimmer [17] proposed a robust index of dispersion based on point-to-individual distances that appears to be a powerful test for spatial patterning. Distance indices offer an improvement over the previously mentioned dispersion indices and statistical distributions [14, 18].

Spatial scale have been stressed as crucial in ecological systems [19]. Marshall [10] showed a large grade of variability in weed maps created using different spatial scales of detection. However, detailed studies on weeds to compare different spatial scale are rare [10] in spite of the importance in the study of spatial pattern [20] and there are not studies showing the scale effect on dispersal indices.

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The purpose of this study was to examine the distance index approach, using the Johnson and Zimmer Index of Dispersion to measure the spatial pattern of weed populations and the effect of spatial scales.

MATERIALS AND METHODS

Study area and data acquisition: The study was carried out in 1997 in a vetch (*Vicia sativa* L.) crop at Encin Research Station, Alcala de Henares, near Madrid, Spain, on a fine loam soil (32% sand, 42% silt and 26% clay), with 1% organic matter and a pH of 8.1. The vetch crop was established under minimum tillage and non-herbicide application, being the sowing rate of 80 kg ha^{-1}.

In April, a plot of 9.0×4.5 m (large scale) was choose. Two sub-plot of 3.0×1.5 m (medium-scale) and other sub-plot of 1.0×0.5 m (small-scale), equivalent to the quadrats used commonly to describe spatial pattern in weeds, were choose a random within the plot. For each seedling plant their corresponding x and y co-ordinates were recorded. Five weed species (*Polygonum aviculare* L., *Papaver rhoeas* L., *Descurainia sophia* L., *Lolium rigidum* Gaudin and *Anacyclus clavatus* Desf. Per.) were identified.

Distance index and statistical analysis: In order to detect the type of spatial pattern, the Johnson and Zimmer Index of Dispersion (I) [17] was used. This index is based on point-to-individual distances. Given a sample of r random points (with x and y co-ordinates,) with distance d_i from the i^{th} point to the nearest weed, then the Johnson and Zimmer index of dispersion is defined as:

$$I = \frac{(r+1)\sum_{i=1}^{r}\left(d_i^4\right)}{\left[\sum_{i=1}^{r}\left(d_i^2\right)\right]^2}$$

where E (I), the expected value of I, have a value approached of 2 for a random distribution (E(I)≅2), E(I)<2 for regular distribution and E(I)>2 for an aggregated distribution [17]. The dispersion index *I* converges to the normality for moderates;

$$z = \frac{(I-2)}{\sqrt{\frac{4(r-1)}{(r+2)(r+3)}}}$$

values of r (e.g r=100), what allow to estimate the statistical z as [17]:

Which under the null hypothesis of randomness is an approximate N(0,1) variate. The z value is compared to a table of critical values for the standard normal distribution to obtain the level of significance of any departures from randomness [17].

To calculate the dispersion index a total de 100 random points with co-ordinate x, y for small scale (r=100), 200 random points to medium scale (r=200) and 300 random points to large scale (r=300) were considered. For each specie, the distance (d_i) from each random point to the nearest weed was estimated and used to calculate I.

RESULTS AND DISCUSSION

Different researchers [9, 10, 17] have found that the aggregate pattern was the general behaviour of the weed species studied, being the negative binomial distribution the most appropriate model for the spatial representation of the weed populations. Our results in this paper do not support these finding. At the three scales considered, the five weed species studied do not present a significance departure from the random distribution (Table 1). However, it is impossible to make a more exact comparison between our observation and the observations of the other authors because of the difference in methodology and species. Moreover, the weed distribution in the crop is the end result of different factors: environmental heterogeneity, natural and artificial seed dispersal.

A common problem fitting statistical distributions is not finding an appropriate distribution model for the adjustment of some data [3]. Wiles *et al.* [9] found some problems to fit data to the binomial negative distribution. Furthermore, the binomial negative distribution has shown to have some ecological limitations, e.g. the parameter k of binomial negative is dependent upon the population mean [21]. Distance index approach avoid such type of problems because is free of distributional

Table 1: I value for different weed species. ns no significance at the 5% level of probability

	Spatial scale		
Specie	Small	Medium	Large
Polygonum aviculare	1.82^{ns}	1.88^{ns}	1.90^{ns}
Papaver rhoeas	1.86^{ns}	1.84^{ns}	1.88^{ns}
Descurainia sophia	1.90^{ns}	1.93^{ns}	1.94^{ns}
Lolium rigidum	1.85^{ns}	1.91^{ns}	1.87^{ns}
Anacyclus clavatus	2.20^{ns}	2.10^{ns}	1.97^{ns}

assumptions and only depend on the exact localisation of the plants.

For weeds, detailed studies to compare different spatial scales are rare and the effects of sampling scales are largely unknown. Clark *et al.* [10] studied the spatial distribution of weed at different spatial scales and concluded that Taylor power law parameters behave unpredictably with changes in spatial scale. In our study the Johnson and Zimmer's Index I showed a robust behaviour to detect the distribution pattern for the scale change considered. It should be noted that our results are based in a area of 40.5 m^2 and bigger scale should be used to have a more accurate estimation of the robust of this index. Our study is intended to shows the use of distance indices in weed science rather than detailed spatial patterns.

This paper shows that distance index can be used to describe weed spatial patterns. However, two main problems arise with the use of distance indices. First the time-consuming in data acquisition. In practice, point-nearest seedling weed distance can be measured rapidly by selecting, in the field, random points and recording the distance from each point to the nearest weed and applying the index. Second, a major problem would be the sensibility of different distance index to cluster and edge effects [22]. Gonzalez-Andujar and Navarrete [15] analysed the same set of data, only a one scale (1.0×0.5 m) using a different distance index (T-square). They found that *Lolium rigidum* and *Anacyclus clavatus* showed an aggregated distribution in contrast with the results presented in this paper for the small scale where both species presented a random distribution. For the other three species both indices presented similar conclusions, so it is necessary have caution using distance index of dispersion to avoid edged effect and to detect clusters.

Clearly, there is a vital need to understand the weed distribution pattern in order to reduce the herbicide application. If the weeds occur in aggregated should be possible to reduce herbicide use by spraying only weed patches. We think that distance index can help. Further work is needed to determine the effect of spatial scale and their relevance to weed management and establish which distance index should be more appropriate to represent the spatial weed pattern.

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