COMPARISON OF VARIOUS SAMPLING METHODOLOGIES FOR SITE SPECIFIC STERILE WILD OAT (*AVENA STERILIS*) MANAGEMENT

J. BARROSO, D. RUIZ, C. FERNANDEZ-QUINTANILLA

CCMA-CSIC, Serrano 115 B, 28006 Madrid, Spain
E-mail: judit@ccma.csic.es

A. RIBEIRO, B. DIAZ

IAI-CSIC, N-III-km 22.8, La Poveda, 28500 Arganda del Rey, Madrid, Spain

ABSTRACT

The ability to manage weed infestations in a spatially precise manner will rely on the availability of efficient methods of mapping weed distributions. We have conducted a study designed to compare four different ground based methods for collecting georeferenced information on sterile wild oat infestation in a winter barley crop. Sampling was done at harvest time (when wild oat panicles are most visible) by scoring panicle density, either from the ground or from a combine, by counting panicle contacts by an observer walking through field transects or by sampling wild oat seed rain on the ground. Although the four methods tested provided similar descriptions of the spatial distribution of this weed, they differed in their costs (considering both, the cost of sampling and the cost of wrong decissions). Defining the location of weed patches from the combine appears to be a relatively cheap and reliable method for the creation of weed management maps to be used in the following season.

INTRODUCTION

Precision weed management is strongly based on the availability of reliable data on spatial variability of weeds. Forcella (1993) suggests that management of spatial variability is worthwhile as long as the degree of variability is large enough to justify the cost of obtaining the information and managing the differences accordingly. In this regard, it is critical that the cost of weed sampling is proportionate with the potential benefits obtained from patch spraying.

To date, several monitoring concepts have been used for patch spraying. The grid weed mapping concept, the most common method used, involves the detection and counting of weeds using grid spacing ranging from 3 to 40 m (Christensen et al., 1999; Rew & Cousens, 1999). Since the cost of grid sampling is inversely proportional to the grid spacing squared, it is very easy for sampling costs to exceed the value in herbicide savings as sampling intensity increases. A higher automation of the process can be obtained by visual evaluation of weed coverage by walking the field with a data logger connected to a GPS system (Stafford et al., 1995). Airborne techniques provide the ultimate in automatic weed detection. Brown et al. (1994) used a multiespectral still video camera from a low flying aircraft and a ground based vehicle (10 m above ground) to detect patches of various weed species in a maize field. Lamb et al. (1999) were able to airborne map patches of *Avena* spp. in a field of seedling triticale; however, at this early stage, the presence of this weed was difficult to detect until it was at a relatively high density (>20 plants m^{-2}).

Discrimination between weeds and crops can be simplified by sampling the fields at flowering, when weed growth penetrates the crop canopy and its flowering structures can be distinguished from those of the crop. Rew et al. (1996) tested a semi-automated system that relies on visual recognition of *Elytrigia repens* spikes from a high-clearance vehicle travelling the crop tramlines at harvest time. The absence of weeds, or presence of low or high weed density was recorded onto dedicated keypads. Thornton et al. (1990) was able to discriminate patches of *Alopecurus myosuroides* at flowering in a winter cereal field from colour aerial photographs.

The goal of the present work is to develop a system that -with a low cost and with sufficient accuracy- can be used to collect georeferenced weed information for the creation of weed management maps to be used in the following season.

MATERIALS AND METHODS

In June of 2000, a weed mapping study was initiated in a winter barley field located in Arganda del Rey (Madrid). Georeferencing sterile wild oat (*Avena sterilis* L.) patch locations was conducted at harvest time (when panicles are more visible), using a backpack DGPS equipment (Omnistar 2100 LR12) and a Fujitsu 2100 pen computer.

Sampling systems

A. Counting panicle contacts. The whole field was semi-systematically sampled by walking parallel transects (every 12 m) and counting the number of contacts of wild oat panicles with a 0.60 stick. Cumulative contacts at the end of each 14 m transect portion were georeferenced and stored.

B. Scoring panicle density from the ground. A visual scoring of the density of wild oat panicles was carried out walking along the same transects described previously. One observation was stored after walking 12 m, scoring the 12 by 12-m surrounding cell area.

C. Scoring panicle density from the a combine. The same scoring system described previously was used by a scout from a combine during harvest of the field. The size of the cell area scored individually was 6 m (the header width) by 12 m.

D. Counting seed rain on the ground. This method was used as a reference to compare the accuracy of the various rating systems to actual counts of wild oat seeds fall on the ground. Immediately after barley harvest, surface (0-2 cm) seeds were counted using a 6 m x 12 m grid and a 0.1 m^2 quadrat.

Scoring system

Considering the risks (yield losses and population growth) associated with non controlling wild oats and the options available for the management of this weed, we established the following population categories:

0. <0.1 panicles m^{-2} / Safety level: no yield loss / no herbicide treatment required the next season.
1. 0.1-1 panicles m^{-2} / Low risk: 5% yield loss / treat at ¼ the recommended rate the next season
2. 1-10 panicles m^{-2} / Medium risk: 10% yield loss / treat at ½ the recommended rate the next season
3. >10 panicles m^{-2} / High risk: 20% yield loss / treat at the recommended rate the next season

This numerical scale was used to score visually wild oat infestation pre-harvest (methods A to C). In the D sampling (conducted after barley harvest), the densities of wild oat seeds present on the ground were assigned to each of these four categories by considering that one panicle produces an average of 50 seeds.

Data analysis

Because sampling points were not coincident in the four methods, the first step was to generate a complementary data set. Semivariograms were previously fit to each data set and category values at 165 random points were estimated by a krigging operation. Pearson correlations among values obtained in the same point with the different methods were calculated. The proportion of points misclassified and the costs of errors associated at the three methods (A to C) were estimated by adding sampling costs to the costs of mistakes (caused either by unnecessary treatments or by yield losses in infested areas not treated). In order to estimate these mistakes, we considered the results obtained from the D method as the "real" infestation. The economic analysis conducted to estimate the costs and benefits associated to the various sampling / weed management systems used the following parameters: barley weed-free yield: 3000 kg/ha, barley price: 108 €/t, straw weed-free yield: 2250 kg/ha, straw price: 30 €/t, cost of the herbicide treatment at the recommended rate: 54.1 €/ha, cost of field sampling: 18 €/h.

RESULTS

The maps obtained from the four sampling schemes indicate a very similar location of wild oat patches (Fig. 1). Pearson correlation coefficients for the three maps (A to C) in relation with the reference map (D) were always significant at 1% (Table 1). Therefore, no significant differences were observed among the populations estimated by the four methods.

However, statistical significance is not synonymous with agronomic significance.Considering that the misclassified area (in relation at the reference map) was relatively high (39 to 47%), we decided to evaluate the economic cost of the herbicide treatment mistakes associated with these errors, either by over-spraying or by under-spraying. Table 2 illustrates the costs of the various possible types of mistakes. The total costs of wrong decisions were relatively similar, with a 2.4 €/ha difference between the most accurate mapping method –visual scores from the ground- and the least accurate –visual scores from the combine (Table 1).

In order to assess the feasibility of site specific wild oat management using these three mapping methods, we calculated the total net returns in each case, comparing these results with those obtained with a no-spray strategy (Strategy E) and with a uniform treatment at the recommended rate (Strategy F). This economic analysis indicates that the highest net returns would be obtained with the site specific-variable rate approach when using visual scores taken from the combine at harvest (Strategy C). In this option, although barley yields were similar to those obtained with the blanket treatment (Stategy F), it was possible to obtain a 39 €/ha saving in herbicides with a 9 €/ha sampling cost (Table 3). The use of the site specific-variable rate approach but using other sampling schemes involves high sampling costs that can not be covered by herbicide savings. It is remarkable that net returns of the no-spray strategy were higher than those of the other options, except Strategy C. This indicates that the cost-effectiveness of herbicide use in this type of situation is doubtful. Similar conclusion has been reached previously in various other cereal production systems (Proven et al., 1991; Scott & Pepper, 1994). Reducing herbicide input by decreasing total area sprayed and product application rates may improve substantially the economic returns of the system.

CONCLUSION

The choice of sampling system and numeric scales is a pragmatic trade-off between the cost and benefit of precision and should not aim at a precision higher than what is relevant for practical decision making. Defining the location of wild oat patches from the combine with a 0-4 visual scale appears to be a relatively cheap and reliable method for the creation of weed management maps to be used in the following season. However, although these maps can give us a good indication of the location of the weed patches, actual seedling densities may change considerably between years and across a given season. Because of this, it is desirable to conduct a verification test prior to herbicide application.

REFERENCES

Christensen, S., Nordbo, E., Heisel, T. & Walter, A.M. (1999) Overview of developments in precision weed management, issues of interest and future directions being considered in Europe. *In* “Precision weed management in crps and pastures”. R.W. Medd and J.E. Pratley, Eds. pp. 3-13. CRC for Weed Management Systems, Adelaide

Forcella, F. (1993) Value of managing within-field variability. *In* “Proceedings of Soil Specific Crop Management: A Workshop on Research and Development Issues” P.C. Robert, R.H. Rust, and W.E. Larson, Eds. pp. 125-132. ASA, CSSA and SSSA, Madison, WI.

Lamb, D.W., Weedon, M.M. & Rew, L.J. (1999) Evaluating the accuracy of mapping weeds in seedling crops using airborne digital imaging: *Avena* spp. in seedling triticale. Weed Research 39: 481-492

Proven, M.J., Coutney, A., Picton, J., Davies, D.H.K. & Whiting, A.J. (1991) Cost-effectiveness of weedcontrol in cereals- systems based on thresholds and reduced rates. Proc. Brighton Crop Prot. Conf. Weeds 3: 1201-1208

Rew, L.J. & Cousens, R.D. (1999) What do we know about the spatial distribution of arable weeds?. *In* “Precision weed management in crps and pastures”. R.W. Medd and J.E. Pratley, Eds. pp. 20-26. CRC for Weed Management Systems, Adelaide

Rew, L.J., Cussans, G.W., Mugglestone, M.A. & Miler, P.C.H. (1996) A technique for mapping the spatial distribution of *Elymus repens*, with estimates of the potential reduction in herbicide usage from patch spraying. Weed Research 36: 283-292

Scott, R.C. y Peeper, T.F. (1994) Economic returns from broadleaf weed control in hard red winter wheat (*Triticum aestivum*).Weed Technology 8: 797-806

Stafford, J.V., Le Bars, J.M & Ambler, B. (1995) A hand held data logger with integral GPS for producing weed maps by field walking. Computers and Electronics in Agricultura 9: 235-248

Thornton, P.K., Fawcett, R.H., Dent, J.B & Perkins, T.J. (1990) Spatial weed distribution and economic thresholds for weed control. Crop Protection 9: 337-342

Table 1. Comparison between “real” infestation level of wild oats (measured by its seed rain) and infestation levels measured by three sampling methods

Method:	A. Panicle contacts		B. Scoring from the ground		C. Scoring from a combine	
Pearson correlation	0.712**		0.765**		0.761**	
Mistakes type	Underspray	Overspray	Underspray	Overspray	Underspray	Overspray
Area (%)	16.4	23.0	29.0	11.5	46.6	0.6
Cost of mistakes (€/ha)	3.8	4.8	6.2	1.7	10.2	0.1
Sampling cost (€/ha)	36.1		36.1		9.0	
Total cost (€/ha)	44.7		44.0		19.3	

** P <0.01

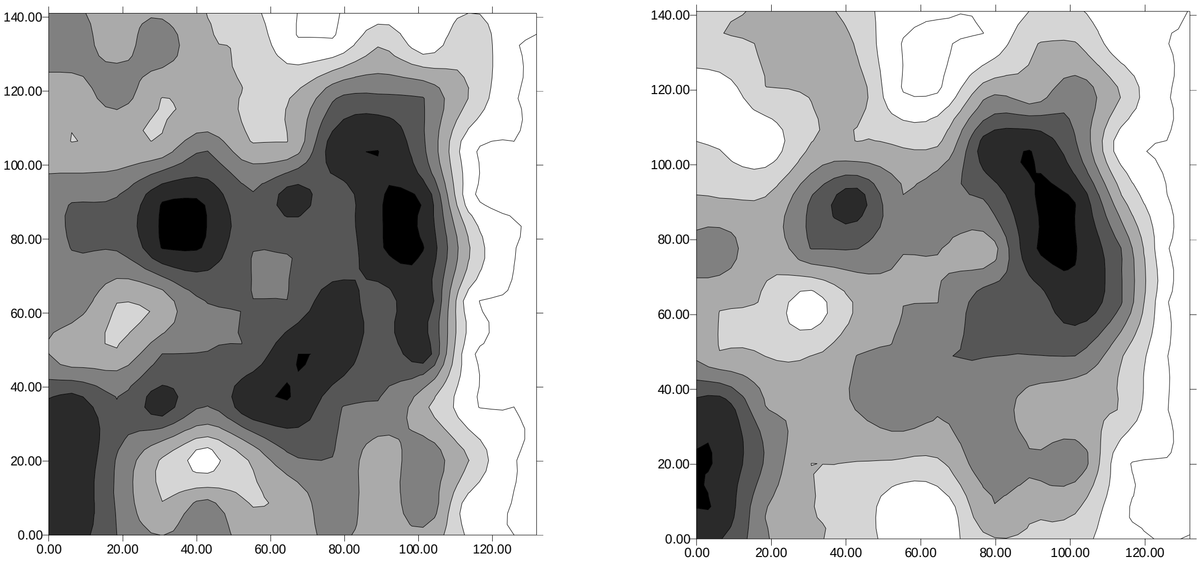
Table 2. Cost of mistakes of various types when comparing the infestation levels measured by the three sampling methods and the “real” infestation level

Level measured	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3
Real level	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Cost of mistakes (€/ha)	0	16.2	32.5	64.9	13.5	0	16.2	32.5	27.1	13.5	0	32.5	54.1	40.6	27.1	0

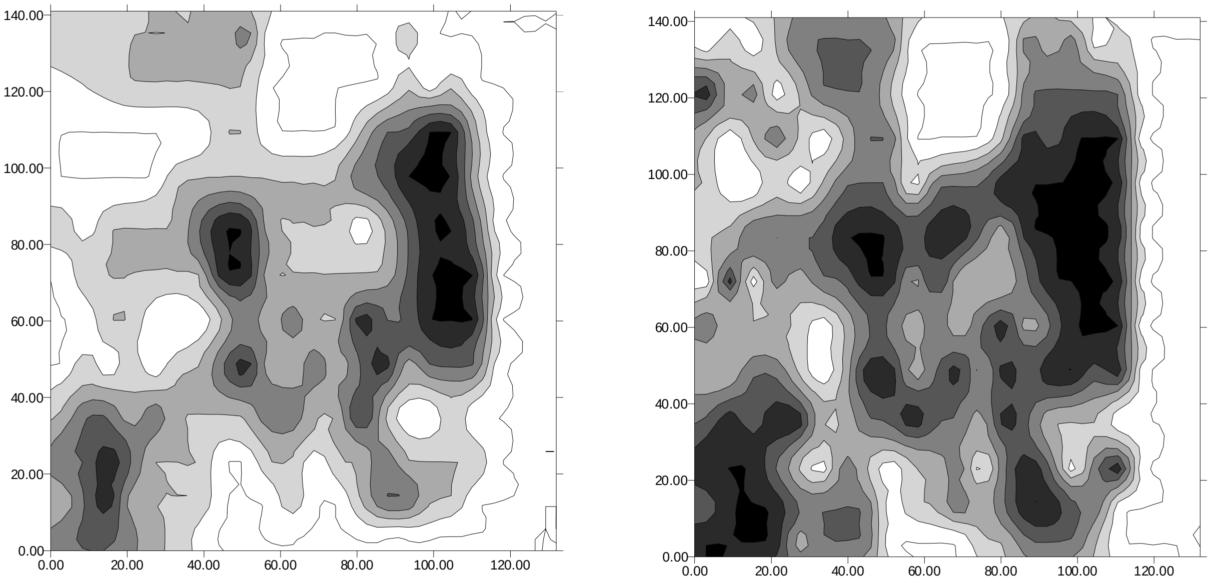
Table 3. Costs, benefits and net returns (€/ha) of three wild oat management strategies and three sampling methods

Spraying strategy	Site specific /variable rate			No spray	Blanket spray
Sampling method	A. Panicle contacts	B. Scoring from the ground	C. Scoring from combine	E. No sampling	F. No sampling
Sampling cost (total)	44.7	44.0	19.3	0	0
Herbicide cost	23.7	19.3	15.1	0	54.1
Fixed costs	289.4	289.4	289.4	289.4	289.4
Yield benefit	392.2	392.2	392.2	354.4	392.2
Net return	34.4	39.5	68.4	65.0	48.7

Fig. 1. Maps of wild oat infestation obtained from four sampling schemes


A. Counting panicle contacts

B. Scoring panicle density from the ground


C. Scoring panicle density from the a combine

D. Counting seed rain on the ground