THESES OF DOCTORAL (PhD) DISSERTATION

UNIVERSITY OF WEST-HUNGARY
Faculty of Agricultural and Food Sciences, Mosonmagyaróvár
Department of Plant Protection

Leader of Doctoral School
Prof. Dr. Kuroli Géza DSC

Sub-program leader
Prof. Dr. Kuroli Géza DSC

Theme leader
Prof. Dr. Reisinger Péter CSC

Development of weed survey methods to planning precision weed control

Written by:
Nagy Sándor

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1. PRELIMINARIES AND OBJECTIVES OF RESEARCH

From the last decades of the 20th century the population of the Earth is increasing in an accelerating way; at the same time the size of agricultural area decreases continuously. Parallel to these, the rising environment consciousness and the sustainable development of agriculture made the development and elaboration of new technologies necessary.

In the 1990's the development of geoinformatics, satellite navigation and the improvement of hardware and software technologies in the USA facilitated the launch of precision agriculture and precision plant protection, that gives solution to the above-written problems.

The aim of precision plant protection treatments is to limit weed and pest control to the optimal pesticide combination and dose, in the possibly smallest area. Therefore weed control is only applied on the field where weed species occur.

To the planning and performing of non-real time site-specific treatments the exact distribution of pests and weeds should be known, that requires weed mapping throughout the field.

It is widely known in practical plant production and protection that the distribution of pests or weeds in agricultural fields is often heterogeneous (a factor that cannot be changed) or patch-like; on the other hand the applied treatments are homogeneous (a factor that can be changed) in the field, applying a table-level technology.

The patch-like distribution of weeds is especially interesting as their detection is more accurate. Stain-like distribution is especially characteristic to perennial weed species with vegetative propagation.

The successful application of precision plant production and precision plant protection assumes the integrated approach of several fields of science (agricultural machinery, microelectronics, software technology, geoinformatics, geodesy, remote sensing, computer aided image processing, soil sciences, agricultural chemistry, plant production sciences, plant protection, gene technology etc.). Nowadays one can say that technical devices are more or less available, „only” the human factor, the professional knowledge is missing to the distribution of this technology, to elaborate and use the elements of the technology on a daily basis. For the practical application of location specific weed management the technical conditions are basically available; but accurate and economic weed detection and weed mapping raise problems.

The objective of the dissertation is to analyse the possibilities of application precision and site-specific technologies, starting with the introduction of basic principles and elements of precision weed control. This objective covers several elements, like the investigation of weed mapping methods that could be applied in precision technologies, the investigation of weed detection based on measurements, the investigation of possibilities of photo-technical and remote sensing methods with the connecting two- and three dimensional weed mapping procedures, the analysis of weed-soil interactions, introduction of population dynamic processes, the planning of simple site-specific and automatic treatments, to elaborate a method that could be used in practice.

2. MATERIAL AND METHOD

Research has been carried out on tables in the surroundings of Baracska and Siklós settlements, and on three neighbouring tables in the region of Mosonmagyaróvár.

The method of defining and density of sampling plots were investigated on the research fields in the region of Baracska, Siklós and Mosonmagyaróvár.

On the Baracska field (size 53 ha) 122 sampling plots were defined in 18 m wide stripes, with 0,5 ha sampling density on the average. On the Siklós field (size 30 ha) 63 sampling plots were defined.

In Mosonmagyaróvár on a part of the investigated field 85 weed detections were carried out with 0,2 ha sampling density; the possibilities to decrease sampling density (0,4 and 0,6 ha) and the application of different sampling methods (grid, only field edges, diagonal) were compared.

Three dimensional weed maps were produced from the investigated fields. First the data of the sampling plots (EOV coordinates and weed cover data) were registered in Microsoft Excel tables. Data have been processed with the Excel. The order of dominancy, percent rate of annual and perennial species, the distribution of certain life-forms, the distribution of so-called bio-ecological spectra (annual monocotyledonous, annual dicotyledonous, perennial monocotyledonous, perennial dicotyledonous), the rate of monocotyledonous and

dicotyledonous species. The appearance frequency (K value) of certain weed species was defined.
Position and weed cover data were registered in the ERDAS Imagine 8.5 Professional softvare; the weed canopy and the appearance of certain weed species were illustrated with three dimensional digital elevation models.

Patches of perennial weeds were measured on two fields and the weed patches were illustrated on maps. Tables were surveyed in 20-30 m stripes, weed patches were walked around in case of fields in the Baracska and Mosonmagyaróvár region. Weed patches were registered as area-like objects (as polygons), with 10 seconds position logging. Patches under 1 m^2 were not considered. The unprocessed data were converted to ESRI shapefile; data processing and weed mapping were elaborated with the ArcView GIS 3.2 software.

The relationship between several soil characteristics (soil texture, humus content) and weed distribution was investigated on the fields around Baracska. Soil maps that were elaborated with the above written methods were visually compared with the weed maps.

With the processing of data of four separate weed surveys (September 2001, April 2002, May 2002 two occasions) the population dynamic changes should also be observed.

On the Mosonmagyaróvár field a weed control technology based on the tank capacity of the sprayer was elaborated. The approximately 20 ha large field was divided into three parts. Each part facilitates a 7-7 and 3 way-and-back turns with 2000 l tank capacity (240 l/ha) and 18 m wide sprayer width.

In plot and small plot trials, and also on table level the utilisation possibilities of remote sensing in weed detection and weed mapping were investigated.

Multispectral images of the weed sampling areas were made to facilitate the comparison of the estimation (Balázs-Újvárosi method) and the measurement methods, to investigate weed canopy.

3. NEW SCIENTIFIC RESULTS

1. The systematically marked, grid point like weed detection results represent the weed distribution of the investigated fields well. If the sampling density is high enough, the weed survey method is insignificant as high sampling density eventuates similar results.

2. Investigating the marking density of weed sampling areas it can be stated, that a 0,5 ha sampling density represents the weed distribution well. In case the density of sampling area was increased, the weed dominancy did not change significantly.

3. Perennial weed species with patch-like appearance can be detected with walking around using GDP receiver in a more accurate way than applying systematic weed survey methods.

4. The elaborated three dimensional weed maps illustrate the spatial distribution of weeds of agricultural fields well.

5. Weed-soil interactions can be well illustrated with comparing soil maps and weed distribution maps.

6. The mapping of the most important soil characteristics (soil texture, humus content) assists the planning process of site-specific and precision pre-emergence treatments.

7. The elaborated weed maps illustrate not only the spatial changes of the weed cover but also the temporal changes, therefore the population dynamic processes of the investigated fields can be well illustrated.

8. A systematic sampling area width that is equal with the sprayer width facilitates the application of non-automatic weed control (field part specific treatment) that can be changed at each tank filling.

9. To elaborate high accuracy weed survey and to plan precision weed management the utilisation of DGPS assisted sensors, orto-images of remote sensing is possible.

10. In case of remote sensing to detect weed species with suitable accuracy, at least multispectral, but even hyperspectral images should be taken.

11. With taking multispectral images the detection of weed canopy is more accurate and reliable with a stable error rate, compared to the use of traditional estimation methods.

4. CONCLUSIONS AND RECOMMENDATTIONS

Technical development processes of the last decades (development of hardwares and softwares, geoinformatics, global positioning system, remote sensing and automation of agricultural machinery) facilitated site-specific, precision weed control.

Systems that assist precision agriculture can already be purchased, but these technical solutions were not developed exclusively for plant protection purposes. Therefore nowadays there is no perfect solution for precision plant protection.

Practical solutions of precision weed control require the possible automation of weed detection, the improvement of techniques in order to present exact and measurable results. A basic condition of precision weed control planning and precision technique application is the definition of weed canopy using measurement and high-density sampling rate methods.

Several systematic and grid methods can be recommended to define sampling areas. These definitions (markings) should be objective and uniformly represent the investigated field. On the other hand homogeneous table parts are often surveyed with unnecessarily high sampling density.

Therefore the planning of the sampling method could be more effective with the application of a GIS, e.g. to integrate topographical maps, digital elevation models soil maps or even aerial images in the system.

In case of remote sensing the definition of sampling areas is not necessary, as the whole area is surveyed and evaluated. To elaborate weed maps on basis of aerial images, some sampling areas (AOI: Area of Interest) that are covered with a weed species are needed. For the elaboration of accurate maps orto-corrigated images should be used, as these photos decrease error possibilities and torsions deriving from relief formations.

The timing of weed detection applications are based on biological issues, therefore there is no difference between precision weed control or using traditional methods in this respect.

Higher sampling density ensures higher accuracy, but it is labour demanding and costly. In each case the right sampling density should be defined to ensure suitable data and cost-effectiveness, and to avoid unnecessary costs. Of course as a speciality of precision technologies general solutions cannot be given; each solution is site-specific and requires a unique sampling area definition and density on basis of local characteristics and objectives of the treatment.

Weed maps illustrate the spatial and temporal changes of the weed patches or canopy well. To apply precision treatments such weed maps are needed that are more accurate than spraying maps.

It is recommended to sample the corners of the table, even if the weed cover will be 0 on the weed map. Besides the ERDAS Imagine software other programs can also be used (e.g. Surfer) to elaborate three dimensional weed maps. Vector-based software could be suitably used for two-dimensional maps as well.

At the elaboration of weed maps based on sampling, the suitable interpolation method is a key element. Therefore the applicability of the closest interpolation algorithms should be investigated later as well.

When using the walking around method to detect weed patches, the definition of the possibly smallest patch to be registered is needed. The smallest the weed patch, the more often position logging should be set in the GPS software.

The definition of weed patch borders is relatively subjective; therefore similar to application maps a puffer zone should be left around the patch.

To define the relations between soil characteristics and weed distribution mathematical statistical and geostatistical methods should also be used.

In order to illustrate and evaluate population dynamic changes at least 2-3 years weed detection data should be available.

To the improvement of variable application of chemicals (based on tank filling) investigations should be carried out in different fields and among different weed distribution conditions.

There are considerable possibilities of utilising remote sensing for precision weed control. Perhaps the most important limiting factors are the weather effect and high costs (although these costs are more favourable if calculated for an area unit, for 1 ha).

The application of the suitable spectral and geometrical resolution is a key element. In case of precision weed control research and also in practice colour aerial photos could be used; for more accurate investigations the use of multispectral technologies are highly recommended.

Multispectral images facilitate the separation of the weed canopy and the detection of some weed groups. After successful pre-emergence treatments, on stubble fields, for the application of total active ingredients (in glyphosat tolerant crops) multispectral images provide a useful solution.

In case hyperspectral technology spreads and becomes common in practice, it could be widely used in remote sensing-based weed detection. If hyperspectral images are taken with using suitably high channel numbers the evaluation of certain channels might facilitate the detection of certain weed species as well.

Area Of Interests and area reference measurements are required to the evaluation of hyperspectral images as well. The increasing spectral and geometric resolutions of satellites, the commercialisation of satellite images contribute to the applicability of space born images.

The spread of precision weed management technologies – as one tool of sustainable agricultural development – can be assisted by to main factors:

On one hand experts working in different fields of science (herbology, machinery operation, geodesy, geoinformatics etc.) should cooperate in a more intensive and effective way. As technological circumstances are more or less available, their systematic improvement and application for practical use are needed with the necessary decision-making options and input possibilities. The other element is integration, advisory service and such service that opens the technology for smaller agricultural farms. This element can be assisted by financial and legal conditions provided by the government to encourage the use of the technology.

If these above detailed elements are coordinated and achieved together, precision technology could be an effective tool for the increasing environmental and economical concerns that are experienced also in weed control.

5. SUMMARY

The main objective of the dissertation is to improve weed detection methods to assist precision weed management planning.

The first part of the dissertation illustrates the requirements and challenges of sustainable agriculture concerning plant protection; precision technology could be one answer to these challenges. In the frame of the given size limits it introduces the satellite-based positioning system as a basic condition of precision weed control, the system of data collection and processing (GIS), and the automatic variable application technique.

The author investigated the possible definition methods of weed survey sampling areas. Systematic methods illustrated the weed distribution and cover of a field in a reliable way on the investigated field; larger homogeneous table parts are often sampled unnecessarily, but in heterogeneous fields even the defined sampling density could not be enough. Therefore for the definition of sampling points the evaluation of input data of geoinformatics systems is highly recommended.

The used 0,5 ha sampling density on the investigated fields illustrated the weed cover of the fields well, but for the application of precision treatments a more accurate measurement density is needed. A 0,6 ha sampling density gave similar weed cover results than the 0,2 ha sampling density. It is always a compromise to define a sampling density that ensures suitable accuracy in a cost-effective way.

The author elaborated three dimensional weed maps with the use of ERDAS Imagine software to investigate the spatial distribution of weeds on the investigated tables.

In case the same field is surveyed in different times, the elaborated weed maps make the visual illustration of population dynamic changes possible and facilitate the forecast of weed appearance. To provide more accurate evaluations a longer investigation period is needed.

Weed-soil interactions can be well illustrated with comparing soil maps indicating the most important soil characteristics (soil texture and humus content) and weed distribution maps.

In case perennial weed patches are detected with walking around using GPS receiver and weed maps are elaborated from these data, such maps could be used as inputs for precision treatments in a labour effective way.

A systematic sampling area width that is equal with the sprayer width facilitates the application of non-automatic weed control (field part specific treatment) that can be changed at each tank filling.

The presented multispectral images taken from low heights ensure a more accurate canopy measurement than the traditional estimation methods.

To the further improvement of precision weed control methods that can be used in practice, further investigations are needed.

Research carried out by the author contributes to the further development of conditions of precision weed control; the practical application of this precision technique results considerable chemical savings.

6. PUBLICATIONS IN THE TOPIC OF THE DISSERTATION

6.1. Reviewed articles published in professional periodicals:

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11. Reisinger, P., Nagy, S., Sárkány, V. (2003): Gyomflóra vizsgálatok őszi búzában 10 éves monokultúrás kukoricatermesztést követően. Magyar Gyomkutatás és Technológia. 4. (2) 57-63.

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13. Reisinger, P., Lehoczky, É., Nagy, S., Kőmíves, T. (2004): Using GPS in weed prediction. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz. (Journal of Plant diseases and Protection). Eugen Ulmer GmbH & Co., Stuttgart. Sonderheft XIX. 399-403.

6.2. Presentations on scientific conferences:

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6. Reisinger, P., Lehoczky, É., Nagy, S., Kőmíves, T. (2004): Database-based precision weed management. 22. Deutsche Arbeitsbesprechung über Fragen der unkrautbiologie und -bekämpfung. Stuttgart-Hohenheim, 2004. március 2-4.

6.5. Other publications:

1. Éva Lehoczky, Péter Reisinger, Sándor Nagy, Tamás Kőmíves (2003): Crop-weed competition: *Cannabis sativa* L. in winter wheat. 3rd International Plant Protection Symposium at Debrecen University (3rd IPPS). From ideas till implementation. Challenge and Practice of Plant Protection in the beginning of the 21st century. Debrecen, 15-16. 10. 2003. Proceedings. 307-312.

2. Kőmíves, T., Lehoczky, É., Nagy, S., Reisinger, P., Pálmai, O. (2003): A kukorica preemergens gyomirtásának térinformatikával támogatott módszere. III. Növénytermesztési Tudományos Nap. Gödöllő, 2003. május 15. Proceedings. 107-112.

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