Precision weed control in sunflower and maize - experiences from Hungary

Präzise Unkrautkontrolle in Sonnenblume und Mais - Erfahrungen aus Ungarn

Tamas Komives[1]* & Peter Reisinger[2]
[1]Plant Protection Institute of the Hungarian Academy of Sciences, 1022 Budapest, Herman O. u. 15, Hungary
[2]University of West-Hungary, Faculty of Agricultural and Food Sciences, 9200 Mosonmagyaróvár, Vár 2, Hungary
*Corresponding author, tkom@nki.hu

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Summary

In recent years, a Hungarian private farm in Zimany (Southern Hungary) systematically built-up and developed its spatial information infrastructure and enabled us to carry out research on and development of site-specific weed management methods. Over the past four years, our goals were to improve weed control efficacy and to reduce the amount of herbicides applied. We a) developed an off-line, map-based method for pre-emergent precision herbicide treatments to control weeds in maize and sunflower (our application algorithm is based on the humus content and an empirical plasticity index of the soil), and b) in on-line precision post-emergent in-row treatments in maize we used a novel approach to mount mechanically shielded WeedSeeker (NTech Industries) sensor-sprayers on a precision cultivator (Garford Farm Machinery) in order to apply a non-selective (total) herbicide (glyphosate) safely under the leaf canopy.

Keywords: GPS, herbicides, precision agriculture, sensor-sprayers, site-specific weed management

Zusammenfassung

In den letzten Jahren hat ein privater landwirtschaftlicher Betrieb in Zimány (Südungarn) seine räumliche Geoinformations-Infrastruktur deutlich verbessert und die Durchführung der Forschung und Entwicklung von Methoden zur teilflächenspezifischen Unkrautmanagement ermöglicht. In den letzten vier Jahren entwickelten wir eine kartenbasierte Methode (Off-line) für a) Vorauflauf- Präzisionsherbizidbehandlungen in Mais und Sonnenblumen (der angewendete Algorithmus basiert auf dem Humus- und Sandgehalt des Bodens) und für b) Nachauflauf- Präzisionsherbizidanwendungen in Reihen-Kulturen, die eine zwei-Komponenten-Herbizidkombination mit variabler Zusammensetzung verwendet (die Dosis und der Anteil der Herbizide ist dichtebasiert). In Online-Präzisionsbehandlungen für Nachauflauf-Unkraut in Mais haben wir WeedSeeker (NTech Industries, USA) Sprühgeräte verwendet, um die Herbizide unter dem Blätterdach anzuwenden.

Stichwörter: GPS, ortsspezifische Unkrautbekämpfung, teilflächenspezifische Landwirtschaft

1. Introduction

During the last two decades, agriculture in Hungary has been completely restructured because of the political and social changes. Most importantly, small private farms replaced the large state-owned cooperatives. Unfortunately, the majority of the new enterprises lacked and many of them still lack the equipment and professional knowledge necessary for good agricultural practice. As a result, agricultural output (quantity and quality) sharply declined and high amounts of weeds in the agricultural fields became a major problem (still unsolved today: large seed banks of noxious weeds can be found in the soils of the majority of farmlands). Thus, in plant protection research we gave high priority to efficient methods of weed control, such as precision weed management.

Under the capital-poor conditions in Hungary, we first focused our research on off-line (map-based) methods (REISINGER et al., 2004) in contrast to the more advanced on-line techniques (GERHARDS et al., 2002; OEBEL et al., 2004) paying special attention to the relationship between soil properties and the efficacy of pre-emergent herbicides (REISINGER et al., 2008). Briefly, we found that the optimum dose of the pre-emergent herbicide (within the recommended range of the dose in the registration file) is linearly dependent on the humus content (H) and the empirical soil plasticity index of Arany (K_A) used for estimating the soil water retention capacity (REISINGER et al., 2008).

Thus, after building the weed map of each field, a treatment regime was designed to be carried out at a later date. The main problem with this method was that the control steps were extrapolated from data obtained earlier. Thus, weed control efficacy was highly dependent on the accuracy and resolution of the map and the predictive power of the data. We used this approach for developing pre-emergent herbicidal treatments in sunflower and maize.

It is important to note that pre-emergent herbicides can only be applied within a narrow dose range (typically 20 % below the maximum). Thus, the legal dose options are zero or one within this registered range. Since agricultural fields in Hungary are heavily infested with weeds, when pre-emergent herbicide application is part of the weed control technology, the complete field has to be treated.

2. Materials and methods

2.1 Precision weed control in sunflowers

Investigations were carried out in 2008 in Zimány (Somogy county, Hungary) in a 30 ha field (no. 3104) managed by Farkas, Ltd. The soil type was Eutric Cambisol. Soil nutrient contents were determined in 2005 with a 3 ha sampling frequency. Phosphorus and potassium fertilizers were supplied by precision application during the fall. The experiments on precision weed control were a continuation of those by REISINGER et al. (2007).

The field was well managed: The soil contained relatively low amounts of viable weed seeds and vegetative propagules. Common ragweed (*Ambrosia artemisiifolia*) was the dominant weed but pigweed (*Amaranthus retroflexus*), lambsquarters (*Chenopodium album*), barnyard grass (*Echinochloa crus-galli*) and curly-top knotweed (*Polygonum lapathifolium*) were also present.

Sunflowers were seeded with ±2-cm accuracy (AgGPS autopilot system; Trimble, Sunnyvale, CA, USA). Immediately after seeding, a herbicide combination consisting of Racer (25 % fluorochloridone), Gesagard 500FW (50 % prometrin, since then banned from use), and Dual Gold 960EC (96 % S-metolachlor; all Syngenta, Switzerland) was applied. Standard doses of the above herbicides were 2.0, 1.0, 1.25 l/ha, respectively.

Soil samples were taken with a 'one sample per 3 ha'-frequency. Standard methods were used to determine the soil plasticity index of Arany (K_A) and humus contents (H) (Tab. 1; REISINGER et al., 2008). These data were used to determine the herbicide doses (Fig. 1) applied at a given location in the field according to the empirical equation:

$$\text{Dose} = \text{Min} + 0.011(\text{Max} - \text{Min})\,(K_A + 9.0H)$$

in which Min and Max are the minimum and maximum recommended doses of the herbicide and the empirical soil plasticity index of Arany (K_A) and the humus content (H) are the site-specific variables (REISINGER et al., 2008). These parameters of the soil in the particular field were only slightly variable, resulting in minimum and maximum spray volumes of 250 and 260 l/ha, respectively (Fig. 1), within the registered dose range of the herbicide (220 to 270 l/ha).

Tab. 1 Soil properties at the sampling sites used to calculate pre-emergent herbicide doses in sunflower.

Tab. 1 *Bodeneigenschaften an den Probenahmestellen um die Aufwandmenge von Vorauflauf-Herbiziden in Sonnenblumen zu berechnen.*

Sampling site number	Longitude	Latitude	K_A	H %
1	17.92673	46.53106	39	1.87
2	17.92898	46.53111	42	1.55
3	17.93116	46.53273	44	2.02
4	17.92890	46.53267	43	2.04
5	17.92882	46.53423	41	1.44
6	17.92874	46.53579	41	1.74
7	17.93099	46.53584	41	1.88
8	17.92648	46.53573	40	1.84
9	17.92656	46.53417	44	1.95
10	17.92664	46.53262	44	1.73

Herbicides were applied by a Spidotrain 2800/18 RAU machine (Kverneland Group, Kvernaland, Norway), equipped with 12004 IDKT nozzles (Lechler GmbH, Metzingen, Germany). The instruction data set was uploaded in the tractor's on-board computer. After the calibration and setup was completed, spraying was controlled by the high-accuracy DGPS system and the on-board computer.

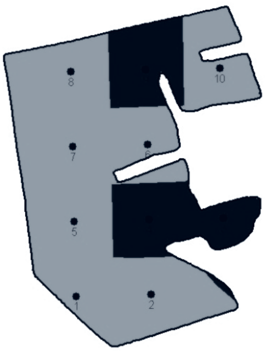

Fig. 1 Map for the field application of the herbicides (spray volume in lighter areas 250l/ha and in darker areas 260 l/ha).

Abb. 1 *Karte für den Feldeinsatz der Herbizide (Sprühvolumens in hellen Bereichen 250 l/ha und dunklen Bereiche 260 l/ha).*

Plants were seeded and the pre-emergent herbicide combination was applied on April 14, 2008. During May, a total of 37.5 mm rainfall was recorded and in June 33.2 mm.

In addition to the above-described field, precision weed control was used in four additional fields (97 ha in total) in 2008.

2.2 Precision weed control in maize

Earlier observations, recently summarized by NOVAK et al. (2009), suggested that in Hungary post-emergent weed control alone may be insufficient because of the large size of the weed seed-banks in the fields. Therefore, we designed a combination of pre-emergent and post-emergent herbicide treatments, applying the latter ones against emerging perennial weeds using a sensor-spraying equipment to control the weeds growing between the crop rows.

Investigations were carried out in Zimány in four maize fields (soil type: Eutric Cambisol, altogether 75.4 ha) managed by Farkas, Ltd. During seeding, rows were recorded with ±2 cm accuracy. A pre-emergent herbicide combination (Lumax, containing mesotrione 37.5 g/l, S-metolachlor 37.5 g/l and terbuthylazine, 12.5 g/l, Syngenta, Switzerland) was used, primarily against annual weeds. Herbicide efficacy was very good, only Bermuda grass (*Cynodon dactylon*) appeared sporadically in one field. Site specific application of the pre-emergent herbicides was carried out as described in 2.1. Soil parameters are listed in Table 2.

Tab. 2 Soil properties at the sampling sites used to calculate pre-emergent herbicide doses in maize.

Tab. 2 *Bodeneigenschaften an den Probenahmestellen um die Aufwandmenge von Vorauflauf Herbiziden in Mais zu berechnen.*

Sampling site number	Longitude	Latitude	K_A	H %
1	17.91553	46.43788	41	1.57
2	17.91937	46.43687	38	1.67
3	17.92072	46.43773	41	1.75
4	17.92072	46.43773	37	2.16
5	17.92197	46.43680	40	2.25
6	17.92062	46.43593	41	1.82
7	17.91927	46.43507	39	1.95
8	17.92052	46.43414	38	1.91
9	17.92187	46.43500	41	2.20
10	17.92322	46.43586	41	1.95

For post-emergence treatments, a cultivator frame (Garford Farm Machinery, Peterborough, UK) was attached to the tractor. On the frame, seven plastic-container shielded WeedSeeker (NTech Industries, Ukiah, CA, USA) sensor-sprayers were mounted 76 cm apart (Fig. 2). WeedSeeker sensor sprayers are optoelectronic devices, in which an optical system analyzes the wavelength of reflected infrared light. Light reflected from chlorophyll containing plants activates the spray nozzle (LU 12004, Lechler GmbH, Germany). During our experiments, sprinkler heads were shielded by 60 cm diameter flexible plastic containers (Fig. 2 and 3). The tractor carried a 1000-liter water tank and an injector (Dosatron, Dallas, USA) to add formulated glyphosate herbicide concentrate (Amega 480SL, 48 % glyphosate ammonium active ingredient; Nufarm GmbH, Austria) amounts proportional to the volume of the spray solution.

Fig. 2 WeedSeeker sensor-sprayers shielded by plastic container.

Abb. 2 *WeedSeeker, sensorgesteuertes Sprühgerät mit Kunststoff-Behälter zur Abschirmung.*

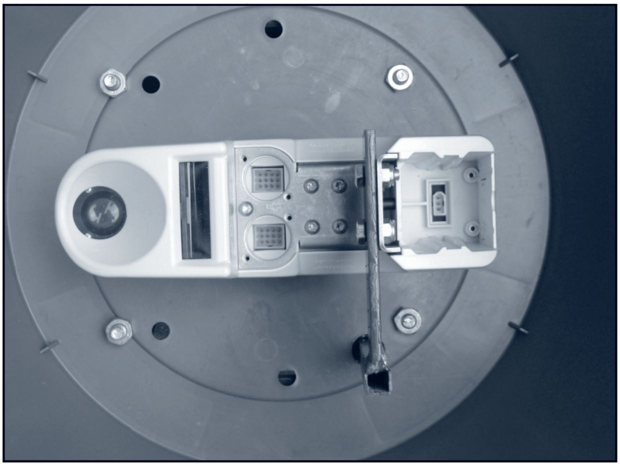

Fig. 3 WeedSeeker sensor-sprayer shielded by plastic container (bottom view).

Abb. 3 *WeedSeeker, sensorgesteuertes Sprühgerät mit Kunststoff-Behälter zur Abschirmung (von unten).*

3. Results

3.1 Precision weed control in sunflower

Following the completion of the herbicide treatment, a spraying map was constructed using the data recorded by the tractor's on-board computer.

Weed control efficacy was first evaluated on June 6, 2008, when sunflowers were in 6-8 leaf stage. The field was completely weed-free and there were no phytotoxic symptoms on the crop plants (Fig. 4).

Fig. 4 Weed-free sunflowers (June 6, 2008).

Abb. 4 *Unkrautfreie Sonnenblumen (6. Juni 2008).*

The second weed scouting was performed on July 11, 2008, during the time of sunflower blooming. Again, the field was completely weed-free.

Fig. 5 Weed-free sunflowers (July 11, 2008).

Abb. 5 *Unkrautfreie Sonnenblumen (11. July 2008).*

Although herbicide saving in this particular field was not significant (<2 %), no herbicide phytotoxicity to the crop plants was observed: Their fitness was excellent and the yield high (3.6 t/ha).

3.2 Precision weed control in maize

In maize, the use of precision weed control by applying pre-emergent herbicides on 75.4 hectares led to a 14 % reduction in herbicide use and to savings 10.3 €/ha. The maize field remained weed-free until the end of the growing season (Fig. 7).

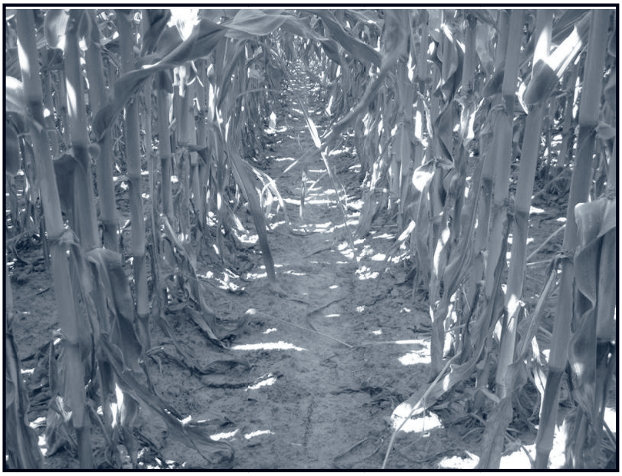

Fig. 6 Weed-free maize field (July 19, 2008).

Abb. 6 *Unkrautfreies Maisfeld (19. July 2008).*

In Hungary, pre-emergent herbicides are still used widely, although it is known that these herbicides cannot control perennial weeds (e. g. Canada thistle [*Cirsium arvense*]), and are inefficient in the absence of soil humidity. To improve weed control in such cases, we developed a method in which glyphosate is sprayed by WeedSeeker sensors directed under the canopy of the crop plant.

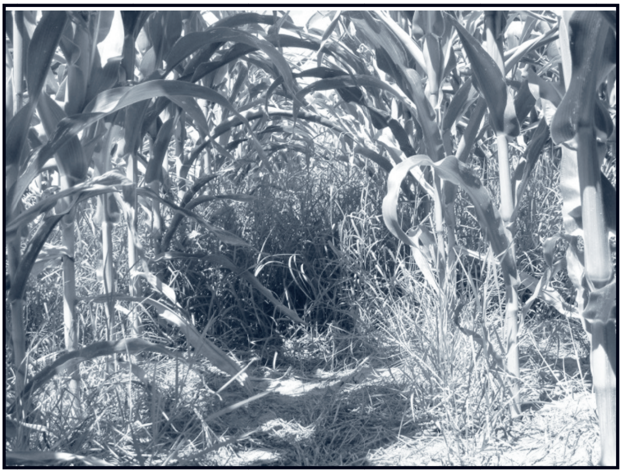

Fig. 7 Control of Bermuda grass (*Cynodon dactylon*) in maize by precision application of glyphosate (front: treated, back: untreated; July 19, 2008).

Abb. 7 *Kontrolle von Bermudagras (Cynodon dactylon) in Mais durch präzise Anwendung von Glyphosat (im Vordergrund: behandelt, im Hintergrund: unbehandelt; 19. July 2008).*

It is interesting to note that the precision application of glyphosate on leaves of Bermuda grass (*Cynodon dactylon*) between the rows led to an efficient control of this weed within the row, too, because the herbicide was translocated within the plant to parts of the plant that were unexposed.

Following the development of the method, precision pre-emergence herbicide applications in maize were successfully used in increasing areas around Zimany, expanding to 201 ha in 2011.

4. Discussion

We developed precision weed control methods for sunflower and corn and used them in large agricultural fields. Weed maps created in earlier years were used to design the control measures. This off-line approach was preferred because the other input data (related to soil properties) were already available. Our approach was especially successful in fields with highly variable terrain conditions: We reduced the costs of weed control and the risk of crop damage by herbicide overdose.

In sunflower, failure of pre-emergent treatments because of rainfall deficit may be successfully counteracted by mechanical weed control using a ridge-plough to turn a thick layer of soil in the row, thereby controlling the weeds growing in the rows, as well. This solution meets the requirements of integrated weed management.

In maize, soil properties were used to calculate the site-specific dose of the pre-emergent herbicide. In case of insufficient efficacy, we recommend a precision, post-emergent application of the non-selective (total) herbicide glyphosate sprayed under the canopy. The herbicide-saving, environment-friendly use of the WeedSeeker sensor provides a solution which combines the map-based and on-line methods. The first use of mechanically shielded WeedSeeker sensor-sprayers in order to keep fields of row-crops weed-free after pre-emergent herbicide applications by applying a non-selective herbicide revealed that the device can be applied safely and successfully.

In summary, the use of site-specific weed control methods allows a significant reduction in environmental pollution, a major goal of the European Union (NORDMEYER, 2006).

Acknowledgements

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