Report on the feasibility and benefits of spot spraying

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Summary

In recent years two private farms in Zimany and in Gyor-Kismegyer (in South and North Hungary, respectively) established and systematically improved their spatial information infrastructure and generously allowed us to carry out research and development studies on site-specific weed management methods. Over the past three years, our primary goal was to improve common ragweed (*Ambrosia artemisiifolia*) control efficacy and to reduce the amounts of the herbicides used for this purpose. We tested the potential of different site-specific methods of herbicide applications to control common ragweed under field conditions. Thus, in wheat stubble we applied the non-selective (total) herbicides glufosinate and glyphosate by using WeedSeeker (NTech Industries) sensor-spot sprayers, and in maize and sunflower we used map-based site-specific application of preemergent herbicides, in combination with spot-spraying glyphosate under the leaf canopy according to the newly developed in-row treatment method that uses mechanically shielded WeedSeeker sprayers mounted on a precision cultivator (Garford Farm Machinery). Precision weed control methods showed higher than 95% weed control efficacy (resulting in fields practically free of common ragweed), and, depending on the weediness of the plot, up to 60% reductions in the amounts of herbicide used.

Introduction

During the last quarter century agriculture in Hungary has been completely restructured because of landslide 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 for many years and high weed infestations in 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), with common ragweed (*A. artemisiifolia*) having the highest cover. Therefore, in plant protection research high priority was given to studying efficient methods of controlling common ragweed. Aiming at reducing environmental and human health hazards as well as costs of weed control by herbicides we focused our efforts on using methods of precision weed management to suppress germination and growth of common ragweed.

Generally, map-based and online techniques are used for controlling weeds in a site-specific, precision manner (Reisinger et al. 2012). The map-based method involves thorough weed scouting, preparation of precision treatment maps, and patch herbicide application. On-line techniques, on the other hand, use real-time, sensor-driven site-specific, spot spraying weed management methods (Andujar et al. 2012; Moshou et al. 2013; Torres-Sanchez et al. 2013) to overcome many of the scouting and map-making costs (Swinton 2005).

We investigated the common ragweed controlling efficacy of precision applications of the non-selective herbicides glyphosate and glufosinate using the WeedSeeker spot sprayer alone (for controlling common ragweed in wheat stubble) or as component integrated into complete weed control technologies in maize and in sunflower.

Materials and Methods

Field experiments

Investigations were carried out in 2011-2013 in Zimány (Somogy county, Hungary) and in Gyor-Kismegyer (Gyor-Sopron county, Hungary) in agricultural fields managed by Farkas, Ltd. and Megyer-Agro Ltd., respectively. The soil types in Zimany and in Gyor-Kismegyer are Eutric Cambisol and Mollic Fluvisol, respectively. Soil nutrient contents were determined in 2008 with a "one sample per 3 ha" sampling frequency. Precision application of herbicides and precision mechanical weed control followed previous lines (Reisinger et al. 2007). Fields in Zimany and Gyor-Kismegyer were well managed: the soils contained only medium levels of viable weed seeds and vegetative propagules. In both locations common ragweed was the dominant weed but in Zimany pigweed (*Amaranthus reroflexus*), lambsquarters (*Chenopodium album*), barnyard grass (*Echinochloa crus-galli*), Bermuda grass (*Cynodon dactylon*), and curly-top knotweed (*Polygonum lapathifolium*) and in Gyor-Kismegyer maple leaf goosefoot (*Chenopodium hybridum*), lambsquarters, annual mercury (*Mercurialis annua*), and jimson weed (*Datura stramonium*) were also present.

Precision weed control in sunflowers - the map-based method

2013

Sunflowers were seeded with $\pm$2-cm accuracy (AgGPS autopilot system; Trimble, Sunnyvale, CA, USA). Immediately after seeding a herbicide combination consisting of Racer (250 g fluorochloridone) and Gardoprim Plus Gold (312 g S-metolachlor + 187 g terbutylazin; all Syngenta, Switzerland) was applied. Standard doses of the above herbicides were 2.0 and 1.25 l/ha, respectively.

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

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

in which Min and Max are the minimum and maximum recommended doses of the herbicide and the two site-specific variables are H and KA (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, within the registered dose range of the herbicide (220 to 270 l/ha).

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.

Plants were seeded and the pre-emergent herbicide combination was applied on April 16. Precipitation was nearly equal to the average: in April, May, and June a total of 46.4 mm, 78.7 mm, and 68.3 mm rainfall was recorded, respectively.

Precision weed control in maize - the shielded sprayer method (2011)

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 a 4 ha maize fields (soil type: Eutric Cambisol) managed by Farkas, Ltd. During seeding, rows were recorded with $\pm$2 cm accuracy. The field is infested by

Bermuda grass (*Cynodon dactylon*). For the experimental 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 (Figure 1). 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 (Figures 1 and 2). The tractor carried a 1000-liter water tank and an injector (Dosatron, Dallas, USA) to add formulated herbicide concentrates (glyphosate: Amega 480SL, 48% glyphosate ammonium active ingredient; Nufarm GmbH, Austria) amounts proportional to the volume of the spray solution.

Figure 1. WeedSeeker sensor-sprayers shielded by plastic container

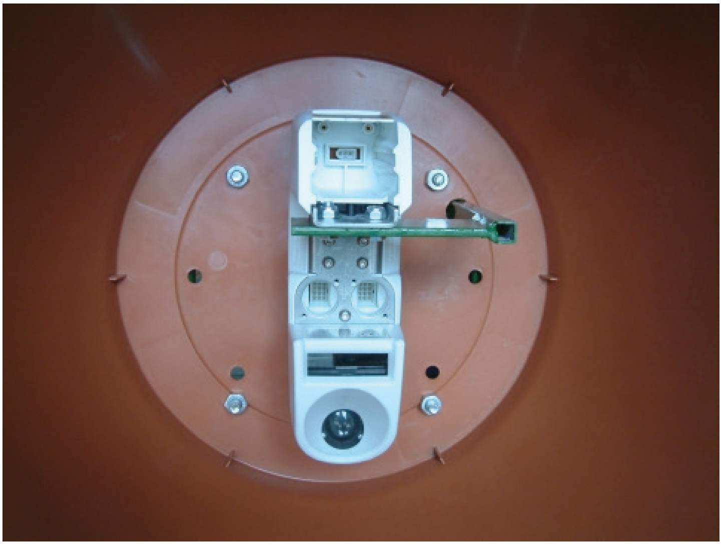

Figure 2. WeedSeeker sensor-sprayer shielded by plastic container (bottom view)

Precision weed control in wheat stubble by spot spraying

Common ragweed seedlings emerge in ripening wheat and after harvest they grow and develop very rapidly reaching 100% cover by the middle of August (Figure 3). Therefore, control of common ragweed in wheat stubble is very important.

2011

Experimental site: a 12-ha wheat stubble field in Zimany with 10 selected sampling sites (1m x 10m, characterized by GPS coordinates), 5 of which are in the herbicide treated area and 5 untreated controls. Soil: Eutric Cambisol, 2.16% organic matter, pH 6.8, containing a large weed seed bank. Winter wheat was harvested on July 05. Weed control on the stubble was done by applying glyphosate using WeedSeeker spot sprayers on August 15 (Common ragweed growth stage BBCH51). Herbicide efficacy survey: August 31.

Figure 3. Emerging common ragweed seedlings in ripening wheat.

2012

Experimental field: 14.8 ha wheat field in Zimany (plot codename: Szentgalosker). Wheat variety: 200 kg/ha Antonius. Date of wheat harvest: July 07. Wheat yield: 6.0 t/ha. Stubble tillage: cultivator on July 14. Date of herbicide application: September 02. Herbicide: Finale 14 SL (150 g/L glufosinate ammonium, Bayer Crop Science), with an application rate of 5 L/ha. Sample sites: altogether ten (2x2 m size, five sprayed with the herbicide and five untreated control). Weed control efficacy was assessed on September19.

2013

Experimental site: a 0.5 ha wheat stubble experimental field at Gyor-Kismegyer with 10 selected sampling sites (2m x 2m, characterized by GPS coordinates, 5 of which are in the herbicide treated area and 5 untreated controls). Wheat harvest: on July 08. Stubble tillage: cultivator on July 16. Weed control by applying Finale 14 SL (150 g/L glufosinate ammonium, Bayer Crop Science), with an application rate of 5 L/ha using WeedSeeker spot sprayers on August 26. (Common ragweed growth stage BBCH51). Herbicide efficacy surveys: on September 05 and September 21.

Results

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 05, when sunflowers were in 6-8 leaf stage. The field was completely weed-free and there were no phytotoxic symptoms on the crop plants (Figures 4 and 5).

Figure 4. Untreated control area and weed-free sunflowers

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

Figure 5. Weed-free sunflowers (July 11)

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).

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 (Figure 7).

Figure 6. Maize field after spot-spray treatment with glyphosate (untreated area in the back)

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.

Figure 7. Control of Bermuda grass (Cynodon dactylon) in maize by precision application of glyphosate

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 (Figure 8), 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 hectares in 2011.

Precision weed control in wheat stubble

2011 - 2013

In all three years of the investigations a single spot spraying of the weeds growing in winter wheat stubble (Figure 8) either by glyphosate or glufosinate led to a complete elimination of the weeds and resulted in a major reduction of herbicide use (in our experiments up to 60%), depending on the weediness of the field. Very few weeds (total weed cover < 5%, efficacy of common ragweed control > 97%) grew on the winter wheat stubble following the spot spraying by glyphosate and glufosinate, and the weeds remaining were stunted and underdeveloped. As a result production of common ragweed pollen and seed in the experimental fields were completely stopped.

Figure 8. Wheat stubble: spot-spray treatment with glyphosate

Discussion

We have tested precision weed control methods (partly developed in our laboratories) to suppress common ragweed in sunflower, maize, and wheat stubble 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 and maize, failure of pre-emergent treatments because of rainfall deficit may be successfully counteracted by a 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 addition, if necessary, a precision mechanical weed control could be applied by 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 wheat stubble a nearly 100% control of common ragweed can be achieved by the spot-spraying application of both glyphosate and glufosinate at the standard rate using the WeedSeeker sensor-sprayer. Therefore, we suggest the inclusion of glufosinate ammonium as an alternative herbicide used in rotation with glyphosate for controlling common ragweed in wheat stubble in order to hinder and postpone the possible emergence of weed resistance to chemical management.

In summary, the site-specific control of common ragweed by spot spraying is highly efficient, allowing a reduction in herbicide use, thereby decreasing the environmental impact of weed control - a major goal of the European Union (Nordmeyer, 2006), in addition to reducing concentrations of the allergenic pollen of common ragweed in the air. A major key for the success of common ragweed control when using this technology will be the management of weed resistance due to recurrent use of glyphosate and glufosinate herbicides.

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References

Andujar, D., M. Weis and R. Gerhards (2012): An ultrasonic system for weed detection in cereal crops. Sensors 12, 17343-17357.

Gerhards, R., M. Sökefeld, A. Nabaut, R. Thergurg and W. Kühbauch (2002): Online weed control using digital image analysis. Zeitschrift für Pflanzenkrankenheiten und Pflanzenschutz, Sonderheft XVIII, 421-427.

Komives, T and P. Reisinger (2012): Precision weed control in sunflower and maize - experiences from Hungary. Julius-Kühn-Archiv 434, 207-215.

Moshou, D., D. Kateris, X-E. Pantazi and I. Gravalos (2013): Crop and weed species recognition based on hyperspectral sensing and active learning. In "Precision Agriculture '13" (Ed. John V. Stafford), Springer, Berlin, pp.555-561.

Nordmeyer, H. (2006): Teilflächenunkrautbekämpfung im Rahmen des Reduktionsprogramms chemischer Pflanzenschutz. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz Sonderheft XX, 165-172.

Novak, R., I. Dancza, L. Szentey and J. Karaman (2009): Arable weeds of Hungary Ministry of Agriculture and Rural Development, Budapest (Hungary) 95 p.

Oebel, H., R. Gerhards, G. Beckers, D. Dicke, M. Sökefeld, R. Lock, A. Nabout and R. D. Therburgc (2004): Site-specific weed control using digital image analysis and georeferenced application maps - first field experiences. Journal of Plant Diseases and Protection Special Issue XIX, 459-465.

Reisinger, P., Zs. Pecze and B. Kiss (2008): Precision developments in the preemergent weed control of sunflower. Journal of Plant Diseases and Protection Special Issue XXI, 177-180.

Reisinger, P., Zs. Pecze and O. Palmai (2007): Evaluation and considering soil plasticity index and humus content when planning precision weed control techniques (*in Hungarian*). Hungarian Weed Research and Technology 8, 59-66.

Swinton, S.M. (2005) Economics of site-specific weed management. Weed Science: March 2005, Vol. 53, No. 2, pp. 259-263.

Torres-Sanchez, J., F. Lopez-Granados, A.I. De Castro, and J-M. Pena-Barragan (2013): Configuration and specifications of an unmanned aerial vehicle (UAV) for early site specific weed management. *PLoS ONE*, 8(3). Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3590160/ [Accessed September 29, 2013]