On-farm investigations on integrated weed management in maize in three European countries

Integriertes Unkrautmanagement in Mais auf Praxisbetrieben in drei europäischen Ländern

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DOI 10.5073/jka.2016.452.027

Abstract

In 2011 and 2012, a total of 9 on-farm experiments were conducted to evaluate the effectiveness of different integrated weed management strategies (IWM) against the conventional approach (CON) in three important European maize producing countries. These sites were located in Italy, Germany and Slovenia and represent the range of various geographic, climatic and cultivation types in Europe. The IWM strategies tested were: 1) Italy: the early-post emergence herbicide broadcast application when-if indicated by a predictive model of weed emergence after performing one scouting in the field, followed by hoeing, 2) Germany: the early-post emergence band application combined with hoeing followed by a second hoeing and 3) Slovenia: the harrowing at BBCH 12-13 of maize and low doses of post-emergence herbicide. Results showed that the different IWM strategies tested in the countries were similarly effective with the CON broadcast herbicide application in reducing weed density. In terms of mean weed density in the 3 countries and 2 years the efficacy of CON was significantly higher than IWM in only 2 out of 6 trials across two growing seasons. Furthermore, there were no significant differences of both management strategies in terms of grain yield. The study highlights the potential of IWM tools already available in Europe

Keywords: Herbicide reduction, maize yield, mechanical weed control

Zusammenfassung

An insgesamt 9 Standorten in 3 wichtigen europäischen Maisanbaugebieten wurden 2011 und 2012 auf Praxisbetrieben vergleichende Versuche mit Verfahren des integrierten Unkrautmanagements (IWM) und der konventionellen Unkrautbekämpfung (CON) durchgeführt. Die Versuchsstandorte lagen in Italien, Deutschland und Slowenien und repräsentieren unterschiedliche geographische, klimatische produktionstechnische Bedingungen in Europa. Folgende IWM-Strategien wurden getestet: 1) Italien: Herbizid-Flächenbehandlung im frühen Nachauflauf nach Bonitur und standortspezifischem Entscheidungsmodell, gefolgt von Hackmaßnahme; 2) Deutschland: Herbizid-Bandspritzung in Kombination mit Hackscharen und nachfolgende Hackmaßnahme und 3) Slowenien: Striegeln im BBCH 12-13 und Flächenbehandlung mit reduzierten Herbizid-Aufwandmengen. Die Versuche zeigten, dass die verschiedenen IWM-Strategien in den Ländern die Unkrautdichte signifikant reduzieren konnte. Bezogen auf die mittlere Unkrautdichte in den 3 Ländern und 2 Jahren war die Wirksamkeit der konventionellen Behandlung (CON) nur in 2 von 6 Versuchen signifikant höher als die der integrierten Varianten (IWM). Die Kornerträge vom Mais unterschieden sich in keinem Fall signifikant voneinander. Die Untersuchungen verdeutlichen das Potenzial von IWM-Methoden, die bereits in Europa zur Verfügung stehen.

Stichwörter: Herbizidreduktion, Maisertrag, mechanische Unkrautbekämpfung

Introduction

Integrated weed management (IWM) is a major component of integrated pest management (IPM) aiming at optimizing crop production and grower's profit through the concerted use of preventive tactics, scientific knowledge, management skills, monitoring procedures, and efficient use of control practices (BUHLER, 2002). IWM has the potential to reduce weed infestation to acceptable levels, reduce the environmental impact of weed control measures, increase cropping system sustainability, and reduce selection pressure for weed resistance to herbicides (HARKER and O'DONOVAN, 2013). Consequently, one of the main challenges in European research is to develop IWM strategies that manage weed infestations with a low dependence on herbicides. These

strategies can satisfy the rising public concern about the massive use of pesticides and will significantly contribute to addressing the EU's strategic commitment to the sustainable use of pesticides by promoting the implementation of IPM, which became compulsory in the EU by the Directive 2009/128/EC (EUROPEAN PARLIAMENT, 2009). Thus, the aim of this study was to investigate the efficiency of different IWM tools which are already available on the market but not yet widely implemented for practical farm uses.

Materials and Methods

In 2011 and 2012, a total of 9 on-farm experiments were conducted to evaluate the effectiveness of different IWM strategies against the conventional (CON) approach in 3 different European regions. Northern Italy (5 sites) represented the southern European region where the average characteristics are medium-heavy soils, relatively mild winters and warm-hot summers, water availability (medium-high rainfall or irrigation) and high grain yield potential. The central region was represented by southern Germany (2 sites) that is characterised by mild-warm summers and high grain yield potential. Slovenia (2 sites) is located in the eastern region with continental climate and a medium grain yield potential (Tab. 1).

Tab. 1 Climatic conditions of the trial regions in 2011 and 2012 (April-October).

***Tab. 1** Klimatische Bedingungen in den Versuchsregionen 2011 und 2012 (April-Oktober).*

Country	Sites	2011		2012	
		Precipitation (mm)	Temperature (°C)	Precipitation (mm)	Temperature (°C)
Italy	5	300	18	380	19
Germany	2	410	17	505	17
Slovenia	2	670	16	790	17

In each region, a minimum of 2 different sites were used as the replicates each year. 2 plots (minimum size of 0.5 ha) were created on each of these sites, where one plot was managed with the CON approach against weeds and the other using different IWM strategies for each region. All on-farm experiments were managed with commercially available equipment which is suited for field scale applications.

The IWM strategies tested in the different countries were: 1) Italy: the early-post emergence herbicide broadcast application when indicated by a predictive model of weed emergence after performing one scouting in the field, followed by hoeing, 2) Germany: the early-post emergence band application combined with hoeing followed by a second hoeing, 3) Slovenia: the harrowing at BBCH 12-13 of maize and low doses application of post-emergence herbicide. The choice of herbicide products and doses in the IWM plots was always decided taking under consideration the weed infestation (i.e. species present and density).

Shortly after maize sowing on each site, 14 sampling areas were fixed randomly in the centre of each plot, each of 0.75 m^2 size (75 cm x 100 cm), where the weed assessments were performed. These sampling areas were fixed in order to determine the efficacy of the IWM strategies tested against the CON management during the growing season. Two weed assessments were conducted: before any post-emergence treatments and before harvesting, where the density per weed species was counted. Maize grain yield was determined by harvesting the whole plot using a combine harvester and converting to t ha^{-1} at 14% moisture content. All statistical analysis were performed with Statistica 10 (STATSOFT Inc., 2011). Means obtained by ANOVA were compared using Fisher's protected LSD test at $P = 0.05$ level of significance. Spearman rank order correlation analysis was performed for grain yield, weed density, and graphical comparison was also used to identify general trends. For further details on materials and methods see VASILEIADIS et al. (2015).

Results

The initial weed infestation in the IWM plots across the different sites for 2011 and 2012 was variable but generally low, ranging from 7 to 157 plants m^{-2}, with species richness ranging from 7 to 17 weed species. The most frequent species detected across all experiments were Chenopodium album and *Chenopodium polyspermum*, whereas *Abutilon theophrasti*, *Amaranthus retroflexus*, *Convolvulus arvensis* and *Echinochloa crus-galli* were commonly observed in Italy and Slovenia.

Overall both strategies were effective in reducing significantly weed density, but CON was significantly more effective than IWM (82% vs. 65% of weed control). Effects were stable across countries and years (interactions not significant), despite of the greater weed density reduction in 2012 due to the higher initial density (Fig. 1).

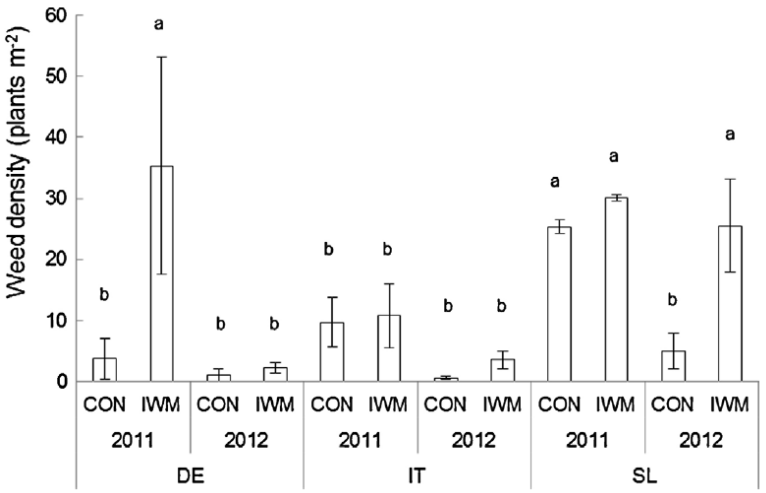

Fig. 1 Effect of different weed management (CON/IWM) on residual weed density in maize.

Abb. 1 *Wirkung von unterschiedlichem Unkrautmanagement (CON/IWM) auf die restliche Unkrautdichte in Mais.*

In terms of weed density, more specifically, in Germany the initial weed density in CON and IWM was similar as no pre-emergence herbicides were applied in both years. The IWM strategy tested in this country (i.e. early post-emergence herbicide application combined with hoeing and followed by another hoeing) had a similar high efficacy as the CON only in 2012 (95% vs. 98%). In 2011, *C. polyspermum* was not controlled efficiently by the hoeing operations between maize rows in IWM, resulting in high final densities compared to the post-emergence broadcast herbicide application in CON that had 86% of weed control. In both years, no significant differences were observed in grain yield between IWM and CON strategies of the German trials (Fig. 2).

In Italy 2011, the pre-emergence application of herbicides in CON was ineffective because of the dry soil conditions, resulting in similar weed density to that of the initial weed infestation in IWM (6 vs. 7 plants m^{-2}). The use of the predictive model in IWM indicated no need for post-emergence herbicide application, thus only hoeing was practiced at all 5 sites, whereas post-emergence herbicide was applied to CON plots in 4 out of 5 sites. This resulted in similar weed control of CON and IWM strategies (final density of 10 vs. 11 plants m^{-2}, respectively). Contrary to 2011, in 2012 the pre-emergence application of herbicides was very effective, with an efficacy of almost 100% for CON and a residual density of 0.5 plants m^{-2} compared to 44 plants m^{-2} in IWM. In this case, the IWM strategy indicated herbicide application in 4 out of 5 sites and resulted in high weed control

(93%) comparable to that of the CON strategy (99%). In both years, there was no significant difference in the grain yields between IWM and CON strategies, but only a strong year effect because of extremely dry season that highly reduced grain yields in 2012.

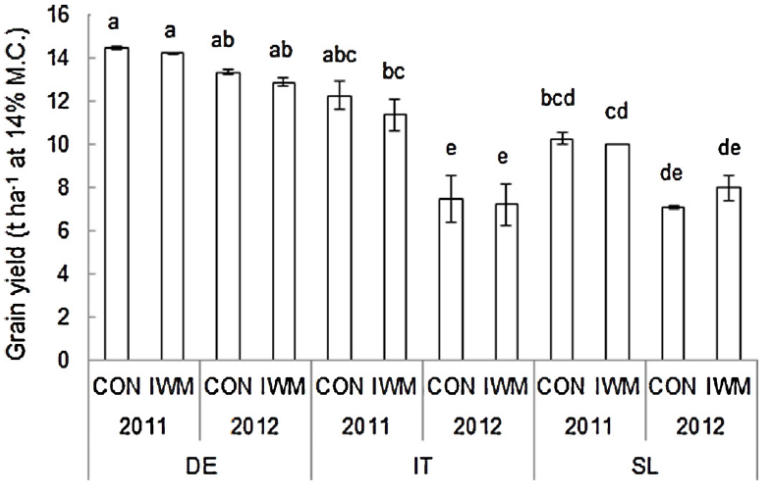

Fig. 2 Effect of different weed management (CON/IWM) on grain yield of maize.

Abb. 2 *Wirkung von unterschiedlichem Unkrautmanagement (CON/IWM) auf den Kornertrag von Mais.*

In Slovenia, the highest initial weed infestation was observed compared to all other countries (70 and 161 plants m^{-2} in 2011 and 2012, respectively). The harrowing combined with reduced herbicide doses provided partial weed control in 2011 compared to the broadcast application of herbicide, and a higher weed control in 2012 when the initial density was higher (57% and 84% weed control in 2011 and 2012, respectively). Also in Slovenia no significant differences in the grain yields between IWM and CON strategies were observed. For more comprehensive results of this study (e.g. on economic effects) see VASILEIADIS et al. (2015).

Discussion

This study indicates that IWM is efficient in controlling weeds without losing grain yield under different growing conditions in Europe. This is remarkable, because this high efficacy, comparable to the broadcast herbicide application, was achieved with old-fashioned technique. Other experimental studies have also shown that weed control and grain yield did not differ in banded herbicide application plus mechanical weeding in maize compared to the broadcast application of herbicides (EADIE et al., 1992; SWANTON et al., 2002). JOHNSON et al. (2002) found that reduced-rate herbicide applications in maize can provide good weed control and maintain a crop yield similar to that obtained with the full-rate.

However, considering the variation of the residual weed density of this study it becomes evident that the IWM strategy may result in high weed seed production before harvest and consequently in weed problems in the succeeding crops. Also it has to be mentioned that on a larger scale (e.g. farms growing more than 30 ha maize) the use of IWM like tested here is limited because of the low area performance and the high risk of unfavourable weather and soil conditions. On the other hand, the findings also demonstrate the strong need for further technical improvements in order to achieve a broad and cost-efficient use of IWM tools in Europe.

Acknowledgements

This research activity was jointly funded by PURE (Pesticide Use-and-Risk reduction in European farming systems with Integrated Pest Management, project number 265865, EU Seventh Framework Programme) and all participating institutions.

References

BUHLER, D.D., 2002: Challenges and opportunities for integrated weed management. Weed Sci. **50**, 273-280.

EADIE, A., C.J. SWANTON, J. SHAW and G.W. ANDERSON, 1992: Integration of cereal cover crops in ridge-tillage corn production. Weed Technol. **6**, 553–560.

EUROPEAN PARLIAMENT, 2009: Directive 2009/128/EC of the European parliament and of the council. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:EN:PDF>.

HARKER, K.N. and J.T. O'DONOVAN, 2013: Recent Weed Control, Weed Management and Integrated Weed Management. Weed Technol. **27**, 1-11.

JOHNSON, B.C., B.G. YOUNG and J.L. MATTHEWS, 2002: Effect of post emergence application rate and timing of mesotrione on corn (*Zea mays*) response and weed control. Weed Technol. **16**, 414–420.

STATSOFT INC., 2011: STATISTICA (DATA ANALYSIS SOFTWARE SYSTEM), VERSION 10. http://www.statsoft.com. StatSoft, Inc., Tulsa, OK, 74104, USA.

SWANTON, C.J., A. SHRESTHA, D.R. CLEMENTS, B.D. BOOTH and K. CHANDLER, 2002: Evaluation of alternative weed management systems in a modified no-tillage corn–soybean–winter wheat rotation: weed densities, crop yield, and economics. Weed Sci. **50**, 504–511.

VASILEIADIS, V.P., S. OTTO, W. VAN DIJK, G. UREK, R. LESKOVŠEK, A. VERSCHWELE, L. FURLAN and M. SATTIN (2015): On-farm evaluation of integrated weed management tools for maize production in three different agro-environments in Europe: agronomic efficacy, herbicide use reduction and economic sustainability. European Journal of Agronomy **63**, 71-78.