Integrated control of annual weeds by inter-row hoeing and intra-row herbicide treatment in spring oilseed rape

Integrierte Regulierung einjähriger Unkräuter durch zwischenreihiges Hacken und Herbizid-Bandapplikation im Rapsanbau

Anders TS Nilsson[1]*, Anneli Lundkvist[2], Theo Verwijst[2], Mikael Gilbertsson[3], Per-Anders Algerbo[3], David Hansson[1], Allan Andersson[1], Per Ståhl[4] and Maria Stenberg[5, 6]

[1]Swedish University of Agricultural Sciences, Department of Biosystems and Technology, P.O. Box 103, SE-230 53 Alnarp, Sweden

[2]Swedish University of Agricultural Sciences, Department of Crop Production Ecology, P.O. Box 7043, SE-750 07 Uppsala, Sweden

[3]JTI - Swedish Institute of Agricultural and Environmental Engineering, Ideon Science Park, SE-223 63, Lund, Sweden

[4]Swedish Rural Economy and Agricultural Sciences in Östergötland, Järngården 13, SE-590 76 Vreta kloster, Sweden

[5]Swedish Rural Economy and Agricultural Sciences in Skaraborg, P. O. Box 124, SE-532 22 Skara, Sweden

[6]Swedish University of Agricultural Sciences, Department of Soil and Environment, Precision agriculture and pedometrics, P.O. Box 234, SE-532 23 Skara, Sweden

*Corresponding author, anders.ts.nilsson@slu.se

DOI 10.5073/jka.2014.443.094

Abstract

The aim of this project is to develop an integrated weed control strategy against annual weeds in spring oilseed rape by means of a combined mechanical and chemical weed control which will be performed concurrently and separately.

The project encompasses field experiments in which different combinations of inter-row hoeing and intra-row herbicide treatments will be evaluated and compared to conventional weed control treatments with broadcast spraying of herbicides, and experiments in which an implement for concurrent inter-row hoeing and intra-row herbicide treatment will be refined and evaluated.

In 2012, an implement for intra-row spraying combined with row hoeing was developed and evaluated in two field experiments in spring oilseed rape in the southern part of Sweden. The effects of inter-row hoeing, intra row spraying, and combination of the two methods were compared with conventional broadcast spraying. Preliminary results showed that the best weed control effects were obtained with the combination of inter-row hoeing and intra-row spraying in both experiments. Regarding crop yield, the yield was significantly higher in the combined treatment in one of the experiments while no effects on the yields were obtained in the other experiment.

We envisage that the inter-row hoeing and intra-row herbicide treatment will diminish the overall use of herbicides to less than one third in comparison with the more conventional chemical weed control methods, while having the same weed control effect.

Keywords: *Brassica napus* L., chemical weed control, crop yields, efficacy, integrated weed management (IWM), mechanical weed control, reduced herbicide doses

Zusammenfassung

Ziel dieser Studie ist die Entwicklung einer integrierten Bekämpfung gegen einjährige Unkräuter im Raps im Frühjahr durch eine Kombination von mechanischen und chemischen Methoden in kombinierter oder separater Anwendung.

Das Projekt umfasst Feldexperimente, in welchen verschiedene Kombinationen von zwischenreihigem Hacken und der Bandapplikation von Herbiziden im Vergleich zu konventionellen Methoden der Unkrautbekämpfung verglichen und analysiert werden. Des Weiteren werden Experimente durchgeführt um ein Werkzeug für die parallele Anwendung der genannten Methoden zu evaluieren und zu verfeinern.

Im Jahr 2012 wurde ein Gerät zur gleichzeitigen Herbizid-Bandapplikation in der Reihe und zwischenreihigem Hacken entwickelt und auf zwei Rapsversuchsfeldern im Südschweden getestet. Die Effektivität von zwischenreihigem Hacken, Herbizid-Bandapplikation und der Kombination aus beiden Methoden wurde mit der konventionellen, ganzflächigen Herbizidapplikation verglichen. Vorläufige Ergebnisse zeigten, dass die

Wirkung der kombinierten Methode in beiden Versuchsanordnungen am höchsten war. In einem der Versuchsfelder war der Ernteertrag mit der kombinierten Methode signifikant erhöht, während in der anderen Versuchsanordnung keine Unterschiede im Ernteertrag feststellbar waren.

Wir erwarten, dass die Kombinationsmethode aus Bandapplikation und zwischenreihigem Hacken die benötigte Gesamtmenge von Herbiziden im Vergleich zur konventionellen ganzflächigen Herbizidapplikation bei gleichbleibender Wirksamkeit reduzieren wird.

Stichwörter: *Brassica napus* L., chemische Unkrautbekämpfung, Ernteertrag, Herbizid-Aufwandmenge, integrierte Unkrautbekämpfung, mechanische Unkrautbekämpfung, Wirkungsgrad

Introduction

Herbicide application is the most commonly used weed control method in crop rotations dominated by annual crops. However, the number of available herbicides is decreasing. At the same time, the development of herbicide resistance is increasing in Europe (KUDSK *et al.*, 2013). Also, farmers within the European Union have to apply integrated pest management (IPM) from 2014 (EUROPEAN PARLIAMENT AND COUNCIL OF THE EU, 2009). This has increased the need for development of alternative weed control measures with reduced amounts of herbicides.

Alternative control methods are mechanical weed control options which are often used in organic farming. For example, row hoeing in growing crops has shown to give control effects sometimes comparable to chemical weed control (MELANDER *et al.*, 2003, 2005). Due to technical achievements regarding steering systems and working width, row hoeing is becoming an interesting weed control technique also for conventional farmers. To decrease herbicide use and lower the risk for development of herbicide resistance, different combinations of chemical and mechanical weed control methods will be more commonly used in the future.

The interest for precision spraying in the crop rows using application widths of 5-10 cm has increased. TILLETT (2005) developed a weed control system for band spraying and interrow-hoeing in cereals. In Spain, a field sprayer for inter- and intra-row weed control was evaluated (CARBALLIDO *et al.*, 2013). HARDY (2013) reported promising results from intra-row spraying in oilseed rape trials performed by Agrovista in UK, and Garford Farm Machinery has developed a hooded sprayer for inter-row spraying with band widths between 10 and 60 cm (ANONYMOUS, 2013).

However, most sprayer nozzles available on the market are adapted for an application width of 20 cm or more. To work properly, these nozzles are adapted to higher flow rates which can be used at an application width of 5-10 cm. In the 1990´s, field experiments in sugar beets were performed to evaluate combinations of intra-row spraying and inter-row hoeing in Sweden (OLHLSON, 1996). The results indicated that the steering systems available for the row hoeing equipment were inadequate. This was also confirmed by HAGENVALL and NILSSON (1997). The technical achievements in precision agriculture, especially regarding inter-row hoeing, are now making it possible to combine intra-row spraying and inter-row hoeing.

In spring oilseed rape cultivation (*Brassica napus* L.), the number of available herbicides is limited. These herbicides are also rather expensive and may pose a threat to the environment. Since it is possible to cultivate oilseed crops at wider row distances without considerable yield losses, it would be interesting to evaluate whether a combination of inter-row hoeing and intra-row spraying could be an efficient weed control method. To evaluate the effects of intra-row spraying and inter-row hoeing on weed flora and crop yields in spring oilseed rape, a research project was initiated in Sweden in 2012.

We envisage that the inter-row hoeing and intra-row herbicide treatment will diminish the overall use of herbicides in comparison with the more conventional chemical weed control methods, while having the same weed control effect.

Material and Methods

Development of equipment for intra-row spraying

During 2012, new equipment for intra-row spraying was developed. A sprayer boom was constructed and sprayer nozzles (Injet 150025, Spraying system) were mounted on the boom. The nozzles had the following traits (at 7 bars): flow rate: 0.15 l $minute^{-1}$ (at 200 l ha^{-1}), spray pattern: 15°, and droplet size: 300 micron. The sprayer boom together with the sprayer tank and pump were installed on an inter-row hoe. The spraying width was 8 cm and the sprayer nozzles were placed about 30 cm above the crop rows. The sprayed area compared with the total area was 32%. The area between the intra-row sprayings was mechanically treated with a goosefoot hoeing machine.

In 2012, two field experiments were performed in spring oilseed rape (*B. napus*) at Kristianstad in the southern part of Sweden. The experimental design consisted of randomised block experiments with four blocks. The treatments included control, broadcast spraying, inter-row hoeing, and inter-row hoeing + intra-row spraying (Tab. 1 and 2). The oilseed crop was sown with a density of 105 seeds m^{-1} in May at a row distance of 12.5 and 25 cm, respectively. Spraying was done when the weed plants had reached 1-2 leaf stage. The herbicide Butisan Top (Metazachlor 375 g l^{-1} and Quinmerac 125 g l^{-1}) was applied with 2 l ha^{-1}. Inter-row hoeing was performed about a week after herbicide application. In June, about four weeks after the last weed control measures, 4 x 0.25 m^2 samples were assessed for weed number and weight per species in each experimental plot. The dry weight of weeds and crop were determined. In August, an area of 20 m^2 was harvested in each plot for determination of crop yields (kg ha^{-1}).

Tab. 1 Experimental design for the field experiment 1 at Kristianstad, Sweden.

Tab 1 *Experimentelles Design für Feldversuch 1 in Kristianstad, Schweden.*

Treatment	Row distance (cm)	Spraying (N = recommended dose)	Inter-row hoeing	Total herbicide dose ha^{-1}* (% of recommended dose)
A	12.5	Conventional spraying (1/1N)	-	100%
B	25	-	-	-
C	25	-	1 time	-
D	25	Intra-row spraying (1/1N)	1 time	32%

* Total herbicide dose ha^{-1} when using an application width of 8 cm.

Tab. 2 Experimental design for field experiment 2 at Kristianstad, Sweden.

Tab. 2 *Experimentelles Design für Feldversuch 2 in Kristianstad, Schweden.*

Treatment	Row distance (cm)	Spraying (N = recommended dose)	Inter-row hoeing	Total herbicide dose ha-1* (% of recommended dose)
A	12.5	-	-	-
B	12.5	Conventional spraying (1/1N)	-	100%
C	25	-	-	-
D	25	-	1 time	-
E	25	Intra-row spraying (1/1N)	1 time	32%

* Total herbicide dose ha-1 when using an application width of 8 cm.

Statistical analysis

Prior to the statistical analyses, the variance of total weed weights and crop yields (residual vs. predicted) were plotted and data were transformed to natural logarithm, in order to stabilize the variance. For each field experiment, the effects of different weed control methods on (1) total weed weight, and (2) crop yield were evaluated in a mixed model containing the main factors block and treatment, and the interaction block × treatment (SAS INSTUTUTE INC., 2010). Least squares means of treatment were separated by the option PDIFF, i.e. all possible probability values for the hypothesis H0: LSM(i) = LSM(j).

Results

In experiment 1, the dominant weed species were *Polygonum aviculare* L., *Chenopodium album* L., and *Sonchus* spp. The results showed that treatment D (inter-row hoeing + intra-row spraying), had significantly lower densities of weeds compared to the other treatments (Tab. 3). The crop yield in treatment B (no weed control) was also significantly lower compared to treatments A, C, and D.

In experiment 2, the weed flora was dominated by the weed species *C. album*. Similar control effects were observed as in field experiment 1. The weed dry weights were significantly lower in treatment B (conventional spraying), D (inter-row hoeing), and E (inter-row hoeing + intra-row spraying) compared with A and C (no control measures). There were, however, no significant differences in weed dry weights between B, D, and E (treatments where weed control had been performed). No differences in crop yield were observed (Tab. 4).

Tab. 3 Mean values of weed dry weight (g m^{-2}) and crop yields (kg ha^{-1}) for each treatment in field experiment 1. Values followed by the same letter are not significantly different.

Tab. 3 *Mittelwerte der Unkraut-Trockengewichte (g m^{-2}) und Ernteerträge (kg ha^{-1}) für jede Behandlung in Feldversuch 1. Werte mit gleichen Buchstaben sind nicht signifikant unterschiedlich.*

Treatment	Weed control methods	Weeds number (m^{-2})	Weeds dry weight (g m^{-2})	Crop yield (kg ha^{-1})
A	Conventional spraying	253,2	87 ^{a}	2140 ^{a}
B	(No weed control)	122,8	176 ^{b}	1804 ^{b}
C	Inter-row hoeing	73,6	80 ^{a}	2196 ^{a}
D	Inter-row hoeing + intra-row spraying	157,2	43 ^{c}	2482 ^{a}

Tab. 4 Mean values of weed dry weight (g m^{-2}) and crop yields (kg ha^{-1}) for each treatment in field experiment 2. Values followed by the same letter are not significantly different.

Tab. 4 *Mittelwerte der Unkraut-Trockengewichte (g m^{-2}) und Ernteerträge (kg ha^{-1}) für jede Behandlung in Feldversuch 2. Werte mit gleichen Buchstaben sind nicht signifikant unterschiedlich.*

Treatment	Weed control methods	Weeds number (m^{-2})	Weeds dry weight (g m^{-2})	Crop yield (kg ha^{-1})
A	(No weed control)	20,6	26 ^{a}	2917 ^{a}
B	Conventional spraying	17,8	12 ^{b}	3107 ^{a}
C	(No weed control)	12,3	25 ^{ab}	2964 ^{a}
D	Inter-row hoeing	6,8	11 ^{b}	2857 ^{a}
E	Inter-row hoeing + intra-row spraying	9,0	7 ^{c}	2857 ^{a}

Discussion

The results from two field experiments in 2012 indicated that a combination of inter-row hoeing and intra-row spraying may give weed control effects comparable to conventional spraying. The observed differences between sites with regard to crop yield response to treatments were probably due to differences in the amount of weeds at the two experimental sites. In field experiment 1, weed abundance was rather high. All performed weed control measures both increased crop yields and decreased weed abundance. In the second experiment, however, weed abundance was lower and no effects of weed control were observed on crop yields.

By using the combination of inter-row hoeing and intra-row spraying, the herbicide input was reduced by 68% compared to conventional spraying. These results are in agreement with a study presented by TILLETT (2005), who developed generic precision row guidance technology for cereal production through targeting of both chemical and mechanical weed control inputs.

During 2013, field studies of inter-row hoeing and intra-row spraying have been performed in spring and winter oilseed rape, winter wheat (*Triticum aestivum* L.), and faba beans (*Vicia faba* L.). If the results from these field studies will be in agreement with the results presented here, the combination of mechanical and chemical weed control may be of great interest for a large part of the farmer community within the European Union.

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