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ORIGINAL ARTICLE

The influence of agronomical and chemical weed control on weeds of corn

Robert Idziak*, Hubert Waligóra, Violetta Szuba

Department of Agronomy, Poznan University of Life Sciences, Poznan, Poland

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*Corresponding address:
robert.idziak@up.poznan.pl

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Abstract

Weeds in sweet corn reduce the yield and are economically more harmful than other pests. The aim of this study was to evaluate the effects of mechanical weed control and efficacy of pre- and postemergence applied herbicides in sweet corn, and their influence on weed control expressed by various indices, corncob yield and net return. Field studies were carried out with preemergence thiencarbazone-methyl + isoxaflutole (at 29.7 + 74.3 g · ha^{-1}), postemergence S-metolachlor + terbuthylazine (937.5 + 562.5 g · ha^{-1}), mesotrione + terbuthylazine (100 + 652 g · ha^{-1}), terbuthylazine + mesotrione + S-metolachlor (656.3 + + 131.3 + 1093.8 g · ha^{-1}), weed free (WF, hand weeding), and mechanical weeding (MW, hoeing) to assess weed control, corncob yield and net return. Variability in potential yield losses was observed between years due to weather conditions at the level of 30 to even 93%. Hand weeding was the most effective, but it is expensive and needs is labour consuming, unlike mechanical weeding which was the cheapest but simultaneously the least effective. Among pre- and postemergence applied herbicides, a mixture of terbuthylazine + mesotrione + S-metolachlor was the most efficacious weed control treatment. It gave high corncob yield and economic net return.

Keywords: net return, sweet corn, weed control

Introduction

Weeds in sweet corn are a severe problem, especially early in the growing season, when there is a slow growth rate of maize during the first weeks after sowing. The inter-rows remain uncovered for a long time and weeds can grow and compete with the maize plants. During this time maize plants are particularly exposed to weed competition (Evans *et al*. 2003). Weeds and environmental variables are some of the most important factors limiting maize production (Doğan *et al.* 2004). Studies (Williams *et al*. 2008) have indicated that due to weed interference over 50% of sweet corn fields suffer yield loss. Weeds can cause yield losses from 5 to 26% to even more than 80% (Gharde *et al*. 2018), making weed control in maize essential to achieve optimal yield. In the European Union low weed management should primarily include non-chemical weed methods but in practice the usage of herbicides is inevitable.

Mechanical methods are used for weed control, mainly in wide row crops like maize, soybean or sunflower (Frondoni and Barberi 2000). For in-row cultivation rotary hoes or inter-row cultivators are usually used (Jhala *et al*. 2014) but only early-season, up to 3–4 leaf stage of maize. Mechanical treatments lowered the weed infestation, even though they were not able to completely control the weeds, because weeds grow within the line of crop plants (Malander *et al.* 2012). Harrowing gave low weed control, although when combined with other mechanical methods (hoeing-ridging, split-hoeing or finger-weeding), it can improve weed control (Pannacci and Tei 2014).

The most effective and popular method of weed control in crops, including maize, is application of herbicides. However, widely used herbicides can contribute to the selection of resistant weeds, which may negatively affect crop quality or have a negative impact on the environment (Felisberto *et al*. 2017). Weed control in maize is based on pre- or postemergence application of herbicides. The time of application depends on many factors, such as moisture levels, temperature, wind speed or relative humidity (Matzenbacher *et al.* 2014).

The aim of this study was to evaluate the effects of mechanical weed control and the efficacy of pre- and postemergence applied herbicides in sweet corn, and their influence on weed control expressed by various indices, corncob yield and net return.

Materials and Methods

Field studies were carried out in 2017–2019 at the Poznan University of Life Sciences Research and Education Center (REC) in Zlotniki (52°48` N, 16°821 E), Poland. The soil at the site was Luvisols (Smreczak and Lachacz 2019), and the soil texture was loamy sand containing 1.1–1.5% organic matter, 64% sand, 15% clay, 21% silt, and pH ranged between 5.7 and 6.9 (Table 1).

The experiment was arranged in a randomized complete block design with four replications. Each plot contained four rows spaced 70 cm apart, 10 m long, and 2.8 m wide. Sweet corn cultivar Hardi was sown at the end of April using a single-row Monosem driller to a depth of 4 cm, and 25 cm spacing within a row. Tillage included moldboard plowing in the autumn and shallow surface cultivation in spring. Mineral fertilizers were applied according to the local recommendations and plant needs, taking into account the nutrient content of the soil and included 75 kg P · ha^{-1} and 90 kg K · ha^{-1} applied in the autumn. Nitrogen at 115 kg · ha^{-1} was applied before planting. The plants were harvested in August each year. The previous crop was maize (2017 and 2018) and oats (2019). Treatments included herbicides thiencarbazone-methyl with isoxaflutole (T + I, Adengo 315 SC, Bayer S.A.S, Lyon, France) at 29.7 g · ha^{-1} + 74.3 g · ha^{-1}, S-metolachlor with terbuthylazine (S + T, Gardo Gold 500 SC, Syngenta, Warsaw, Poland) at 937.5 g · ha^{-1} + 562.5 g · ha^{-1}, mesotrione with terbuthylazine (M + T, Calaris Pro 376 SC, Syngenta, Cambridge, UK) at 100 g · ha^{-1} + 652 g · ha^{-1}, and terbuthylazine with mesotrione and S-metolachlor (T + M + S, Lumax 537.5 SE, Syngenta, Warsaw, Poland) at 656.3 g · ha^{-1} + 131.3 g · ha^{-1} + 1093.8 g · ha^{-1}, weed free (WF, hand weeding, first after weed emergence, then once a week until the end of July), mechanical weeding (MW, two hoeing at the 2–3 and 4–5 leaf stages of maize). The tested herbicides vary according to their mode of action and belong to different HRAC groups: B – thiencarbazone-methyl, F2 – isoxaflutole, mesotrione, K3 – S-metolachlor, C1 – terbuthylazine. T + I was applied preemergence, S + T, M + T and T + M + S postemergence at the stage of 4–5 sweet corn leaves.

Herbicides were applied with a CO_2-pressurized wheelbarrow sprayer equipped with flat fan nozzles TeeJet AIXR 11003, calibrated to deliver 250 l · ha^{-1} at 0.3 MPa. Herbicide treatments were made with 3.0 m boom equipped with 6 nozzles spaced 50 cm apart. Treatment dates and environmental conditions at the time of treatment are shown in Table 2. Weather conditions during sweet corn growth seasons are presented in Table 3.

Fresh weed biomass and the number of weeds were assessed 4 weeks after postemergence application. Biomass and the number of weed species were recorded from two randomly selected rectangles (70 × 50 cm) from each plot. To assess the yield of fresh corncob mass, plants growing in the two middle rows of each plot were harvested. Results were expressed as t · ha^{-1}.

Table 1. Soil characteristics, sweet corn hybrid, planting and harvest dates, seed rates, and application time for field studies conducted in REC Zlotniki, 2017–2019

Year	Soil texture	Soil OM	Soil pH	Maize hybrid	Planting date	Harvest date	Seed rate [no. · ha^{-1}]	Application time
2017	LS	1.5	6.9	Hardi	April 27th	August 28th	57,000	May 18th; June 1st
2018	LS	1.1	5.7	Hardi	April 25th	August 7th	57,000	May 15th; May 24th
2019	LS	1.1	5.7	Hardi	April 25th	August 26th	57,000	May 20th; June 4th

OM – organic matter; LS – loamy sand

Table 2. Weather conditions in REC Zlotniki during spray application

Year	Treatment date	Temperature [°C]	Relative humidity [%]	Wind [m · s⁻¹]	TRAA [mm]
2017	May 18th	19.6	56	1.3	8.6
	June 1st	13.8	78	1.0	32.6
2018	May 15th	15.1	74	2.7	1.4
	May 24th	18.3	63	3.3	115.0
2019	May 20th	17.6	91	2.5	16.8
	June 4th	23.4	61	2.0	4.6

TRAA – total rain 1st week after application

Table 3. Meteorological data at the REC Zlotniki during sweet corn growth seasons, 2017–2019

Month	Years of study		
	2017	2018	2019
	Precipitation [mm]		
April	40.6	36.2	8.6
May	56.8	17.4	94.4
June	68.2	25.6	7.2
July	168.0	70.5	33.8
August	82.0	11.6	28.6
Total	415.6	161.3	172.6
Classification	EW	D	D
	Air temperature [°C]		
April	7.3	12.9	10.5
May	13.7	16.9	11.9
June	17.4	18.5	22.0
July	18.0	20.2	18.9
August	18.9	21.3	20.6
Total	15.1	18.0	16.8
Classification	M	W	W

EW – extremely wet; D – dry; W – warm; M – moderate

Weed management indices were calculated according to the following formulas (Mishra *et al.* 2016; Kumar *et al.* 2019):

1. Weed control efficacy (WCE):

$$WCE = \frac{W_C - W_T}{W_C} \times 100,$$

where: W_C – weed fresh weight in weed check plot, W_T – weed fresh weight in treated plot.

2. Weed index (WI):

$$WI = \frac{Y_{WF} - Y_T}{Y_{WF}} \times 100,$$

where: Y_{WF} – yield from weed free plot, Y_T – yield from treated plot.

3. Weed persistence index (WPI):

$$WPI = \frac{W_T}{W_C} \times \frac{W_{PC}}{W_{PT}},$$

where: W_C – weed dry weight in control (untreated) plot, W_T – weed dry weight in treated plot, W_{PC} – weed population in control (untreated) plot, W_{PT} – weed dry weight in treated plot.

4. Weed management index (WMI):

$$WMI = \frac{\dfrac{Y_T - Y_C}{Y_C}}{\dfrac{W_C - W_T}{W_C}},$$

where: Y_T – yield of treated plot, Y_C – yield of control (untreated) plot, W_C – weed dry weight in control (untreated) plot, W_T – weed dry weight in treated plot.

5. Agronomic management index (AMI):

$$AMI = \frac{\dfrac{Y_T - Y_C}{Y_C} - \dfrac{W_C - W_T}{W_C}}{\dfrac{W_C - W_T}{W_C}},$$

where: Y_T – yield of treated plot, Y_C – yield of control (untreated) plot, W_C – weed fresh weight in control (untreated) plot, W_T – weed fresh weight in treated plot.

Net return was computed according to the value of the increase of corncob yield from herbicide treatments compared to untreated control, taking into account the cost of applied herbicides. The cost of their application was about 11.6 € · ha⁻¹, T + I 36.6 € · ha⁻¹, S + T 45.4 € · ha⁻¹, M + T 31.6 € · ha⁻¹, T + M + S 57.9 € · ha⁻¹, corncob price 116.2 € · t⁻¹ in 2017, 128.5 € · t⁻¹ in 2018, and 125.4 € · t⁻¹ in 2019. Average prices of corncobs, mechanical and hand weed control, and cost of herbicide application were obtained from the local elevator and farm supply cooperative. Statistical procedures were conducted using Statistica 10 software (StatSoft Polska Ltd., Kraków, Poland). The raw data were transformed to arc sine square root to stabilize error variance before analysis, even though all means are presented in their original units. Significant differences between treatments were determined using analysis of variance (ANOVA), and means were separated by protecting Tukey HSD test at $p = 0.05$. The untreated check was not included in the weed control analysis. Yearly treatment interactions were not significant, so 2017, 2018 and 2019 data are presented separately.

Results

Based on meteorological data between April and August, in accordance with the indices (Wanic *et al.* 2005), the years of the field study varied in terms of precipitation and temperature. The year 2017 was very wet and lukewarm, while 2018 and 2019 were warm, but dry (Table 3).

The weed community in the study years consisted mainly of *Chenopodium album* L. (CHEAL), *Brassica napus* L. (BRSNN), *Geranium pusillum* L. (GERPU) and *Fallopia convolvulus* (L.) A. Löve (POLCO) (Table 4). Furthermore, species like *Galium aparine* L., *Tripleurospermum maritimum* (L.) W.D.J. Koch, *Polygonum aviculare* L., *Anchusa arvensis* (L.) Bieb., *Veronica hederifolia* L., *Amaranthus retroflexus* L., *Cirsium arvense* (L.) Scop. and *Stellaria media* (L.) Vill occurred in fewer numbers, and were not seen every year.

Temperature and humidity during preemergence treatment in the consecutive years of the study were, respectively, 19.6°C and 56%, 15.1°C, and 74% as well as 17.6°C and 91% (Table 1). Postemergence herbicides were applied when temperatures in 2017, 2018 and 2019, were 13.8, 18.3 and 23.4°C, and humidity 78, 63 and 61%. Wind speed ranged from 1.0 to 3.3 $m \cdot s^{-1}$. In the first week after preemergence application, precipitation of 8.6, 1.4 and 16.8 mm, and 32.6, 115.0 and 4.6 mm after postemergence application was recorded.

Multiple hand weeding ensured complete control of weeds in sweet corn. In contrast, double inter-plant hoeing was much less effective and reduced the weed population by an average of 24–37%, while in the case of the species presented in Table 4, weed control in the same years ranged from 0 to 45%.

Chemical weed control was clearly more effective than mechanical control (Table 4). Preemergence application of T + I effectively controlled CHEAL in the years 2017, 2018 and 2019, respectively 91, 90 and 100%, as well as POLCO 100, 91 and 100%. In the case of BRSNN lower efficacy of T + I in 2017 was observed. In the next years it was 97 and 100%. The effectiveness of T + I against GERPU varied more, because in the first 2 years, it was only 69–78%, whereas in the last year it was 100%. The mixture of S + T applied postemergence totally eliminated weeds occurring during the field study only in 2019. In the years 2017 and 2018

Table 4. Impact of weed control treatments on weed efficacy (WCE), REC Zlotniki, 2017–2019

Treatment	Dose [g · ha⁻¹]	CHEAL			BRSNN			GERPU			POLCO			Total*		
		2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
WC [g · m⁻²]	–	98	354	310	452	32	83	176	87	158	56	10	12	965	573	896
		Weed control efficacy [%]														
WF	–	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a
MW	–	3d	0d	0a	42c	41c	45b	10c	14c	29c	18c	21d	26b	37c	24d	34d
T + I	29.7 + + 74.3	91b	90b	100a	80b	97a	100a	69b	78b	100a	100a	91b	100a	79b	80c	100a
S + T	937.5 + + 562.0	76c	80c	100a	79b	84b	100a	94a	84ab	100a	70b	74c	100a	81b	78c	94b
M + T	100.0 + + 652.0	100a	100a	100a	100a	100a	100a	99a	70b	79b	100a	100a	98a	98a	88b	87c
T + M + S	656.3 + +131.3 + + 1093.8	100a	100a	100a	97a	86b	100a	97a	100a	100a	100a	100a	100a	97a	93ab	100a

WC – weed check; WF – weed free; MW – mechanical weeding; T + I – tiencarbazone-methyl + isoxaflutole; S + T – S-metolachlor + terbuthylazine; M + T – mesotrione + terbuthylazine; T + M + S – terbuthylazine + mesotrione + S-metolachlor

CHEAL – *Chenopodium album*; BRSNN – *Brassica napus*; GERPU – *Geranium pusillum*; POLCO – *Fallopia convolvulus*

*main weed plus scratch bedstraw, scentless-chamomile, dooryard knotweed, small bugloss, ivy-leaved speedwell, red-rooted amaranth, creeping thistle, and common starwort

The same letter means not significantly different according to Tukey's test ($p \leq 0.05$)

Table 5. Effect of herbicides on weed management indices in sweet corn, REC Zlotniki, 2017–2019

Treatment	Dose [g · ha⁻¹]	*WI*			*WPI*			*WMI*			*AMI*		
		2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
WC	–	–	–	–	1a	1ab	1b	–	–	–	–	–	–
WF	–	0	0	0	0c	0c	0b	0.4a	11.2bc	15.4b	0.4bc	11.2a	15.5b
MW	–	33.7a	55.1a	36.7a	0.7a	4.0ab	0.9b	0.2a	18.2a	27.5a	2.0a	10.7a	21.1a
T + I	29.7 + + 74.3	15.1b	23.5b	6.5c	1.1a	0.7b	0b	0.4a	10.5bc	14.4b	0.6bc	10.8a	14.4bc
S + T	937.5 + + 562.0	6.8bc	22.7b	19.6b	1.1a	0.7b	5.9a	0.5a	7.9c	12.8b	0.7b	8.2b	12.9c
M + T	100.0 + + 652.0	8.8bc	6.7c	18.1b	0.2b	0.4bc	0.4a	0.4a	11.9b	14.3b	0.4c	12.0a	14.5bc
T + M + S	656.3 + +131.3 + +1093.8	10.7bc	7.7c	3.7c	0.1b	1.5a	0.3a	0.3a	11.1bc	14.8b	0.4c	11.1a	14.8bc

WI – weed index; *WPI* – weed persistence index; *WMI* – weed management index; *AMI* – agronomic management index; WC – weed check; WF – weed free; MW – mechanical weeding; T + I – tiencarbazone-methyl + isoxaflutole; S + T – S-metolachlor + terbuthylazine; M + T – mesotrione + + terbuthylazine; T + M + S – terbuthylazine + mesotrione + S-metolachlor
The same letter means not significantly different according to Tukey's test ($p \leq 0.05$)

the effectiveness of the mixture was lower (84%), except for GERPU, whose fresh weight was reduced by 94%. Total weed control efficacy of T + I and S + T was higher only in 2019, 100 and 94%, respectively. In 2017 and 2018 it was 78–81%. The most effective was the mixture of T + M + S – weed control 97–100%, except for BRSNN in 2018 with weed control of 86% (Table 4). Similar activity against CHEAL, BRSNN and POLCO was observed in the case of M + T (98–100%), but it was much lower in 2018 and 2019 in the case of GERPU (70 and 79%). M + T and T + M + S effectively controlled all weeds, 87–98 and 93–100%, respectively.

The data from Table 5 indicated that *WI* was the lowest in hand weeding (0), closely followed by T + M + S (3.7–10.7), M + T (6.7–18.1), next T + I (6.5–23.5) and S + T (6.8–22.7). Weed persistence index (*WPI*) varied between years and treatments, and indicated that S + T treatment resulted in a higher index (0.7–5.9) followed by *MW* (0.7–1.0) and T + I (0.0–1.1). The *WPI* from T + M + S and M + T was the lowest. *WMI* values varied between years whereby in 2017 substantial differences between treatments were not observed (0.2–0.5). In 2018 and 2019 the highest values of *WMI* were obtained from *MW* (18.2–27.5), and lower values from other treatments (7.9–14.8). Just as *AMI* in 2017, values of this index were low and fell within the ambit of 0.4 (treatments *WF*, M + T, T + M + S) and 2.0 (treatment *MW*). In 2018, there were no statistical differences of *AMI* between study treatments (10.1 to 12.0), with the exception of S + T (*AMI* 8.2). The results obtained in the last year of the field study indicated that there were no differences between treatments with herbicides and *WF*. The highest *AMI* value was acquired with *MW* treatment.

Corncob yield varied between years. The highest yield was harvested in the first year, and it was much lower in the following years (Table 6). In 2017 the highest corncob yield was obtained with herbicide and hand weeding treatments (22.4–25.1 t · ha⁻¹). Significantly lower yields were harvested from WC and MW treatments (17.5 and 19.2 t · ha⁻¹). In 2018 and 2019 a very noticeable impact of weed control (independent of treatment) on corncob yield in relation to WC, was observed. In 2018 the highest yield was harvested from *WF*, M + T, and T + M + S. A lower yield was harvested from T + I and S + T, and the lowest yield was from *MW* treatment. In the last year of the study the highest yield was obtained from *WF* and T + M + S, and T + I (12.7, 12.2 and 11.9 t · ha⁻¹). A lower yield came from S + T and M + T (10.2–10.4 t · ha⁻¹), and the lowest was from *MW* treatment (8.1 t · ha⁻¹). The corncob yield from *WC* treatment was invariably the lowest, particularly in the second and the third years of the study (1.4 and 0.8 t · ha⁻¹).

The value of the corncob enhancement is from yield level and unit price. In Table 6 the value of yield in the form of the index was shown, taking the value of the yield harvested from the *WF* treatment as a reference point. The lowest values in all years were obtained from *WC* and *MW*. The most favourable treatment was T + M + S, for value of corncob yield enhancement over 90 every year. In other cases, the value of grain yield enhancement varied more between years. For at least one of the three years of field study, lower values of this index were found. The net return index from

Table 6. Effect of herbicides on weed management indices in sweet corn, REC Zlotniki, 2017–2019

Treatment	Dose [g · ha⁻¹]	Corncob yield [t · ha⁻¹]			Value of corncob yield enhancement			Cost of weed control	Net return*		
					Index** [€ · ha⁻¹]						
		2017	2018	2019	2017	2018	2019	2017–2019	2017	2018	2019
WC	–	15.5c	1.4f	0.8d	70 (2043.3)	8 (179.8)	6 (100.3)	0 (0)	74 (2043.3b)	9 (179.8e)	7 (100.3d)
WF	–	25.1a	16.7a	12.7a	100 (2917.8)	100 (2145.3)	100 (1592.3)	100 (174.4)	100 (2743.4a)	100 (1970.9a)	100 (1417.9a)
MW	–	19.2c	7.5e	8.1c	76 (2231.9)	45 (963.5)	64 (1592.3)	23 (40.4)	80 (2191.5b)	47 (923.1d)	69 (975.2c)
T + I	29.7 + + 74.3	22.4b	12.8c	11.9a	89 (2603.9)	77 (1644.3)	94 (1492.0)	28 (48.3)	93 (2555.6a)	81 (1596.0b)	102 (1443.7a)
S + T	937.5 + + 562.0	23.9ab	9.8d	10.2b	95 (2778.9)	59 (1258.9)	80 (1278.9)	33 (57.0)	99 (2721.9a)	61 (1201.9c)	86 (1221.9b)
M + T	100.0 + + 652.0	23.5ab	15.6ab	10.4b	94 (2731.8)	93 (2004.0)	82 (1304.0)	25 (43.2)	98 (2688.6a)	99 (1960.8a)	89 (1260.8b)
T + M + S	656.3 + + 131.3 + + 1093.8	23.2ab	15.4b	12.2a	92 (2696.9)	92 (1978.3)	96 (1529.7)	40 (69.6)	96 (2627.3a)	97 (1908.7a)	103 (1460.1a)

WC – weed check; WF – weed free; MW – mechanical weeding; T + I – tiencarbazone-methyl + isoxaflutole; S + T – S-metolachlor + terbuthylazine; M + T – mesotrione + terbuthylazine; T + M + S – terbuthylazine + mesotrione + S-metolachlor
*calculations were done based on average prices of grain of maize herbicides and cost of their application
**other treatments in relation to WF
The same letter means not significantly different according to Tukey's test ($p \leq 0.05$)

T + M + S treatment was the most similar to *WF* over the years, at 96, 97 and 103, respectively. Lower net return values after M + T (98, 99 and 89), and T + I (93, 81 and 102) treatment were found. The lowest net return index was obtained from *WC* (74, 9 and 7), and *MW* treatments (80, 47, 69). In contrast, weed control with S + T treatment achieved satisfactory performance only in 2017 (net return 99). It was much lower in 2019 (86), and the lowest was in 2018 (61).

Discussion

Weather conditions, primarily temperature and precipitation during the growing season, have the strongest influence on maize growth and development. Weed development is also highly dependent on the weather, but weeds usually have higher plasticity (Pilipavicius 2015). Conditions that favoured growth and development of sweet corn plants were found only in the first year of study, which was characterized by high precipitation and moderate temperatures. Although maize is a thermophilic plant, temperatures above the optimum (22.5–27.0°C) during grain development can result in yield reduction (Ordóñez *et al.* 2015). However, according to Huang *et al.* (2015) the most significant factor affecting maize yield is precipitation. Our own studies show that a deficit of water and higher temperatures in 2018 and 2019 resulted in lower corncob yield.

Herbicide performance is not only the result of the interaction of herbicide selection, weed community composition and their growth stage (Bellinder *et al.* 2003), but also the weather conditions during and after herbicide application. High relative humidity (above 60%) and air temperature between 10–25°C favour herbicide efficacy (Hatterman-Valenti *et al.* 2016). The weather conditions in REC Zlotniki during application were largely favourable for preemergence, as well as postemergence applied herbicides. The weed community in maize can include many species, but it is generally dominated by a few species that are most abundant, spread the best and have the strongest effect on the crops, limiting its growth, development and yield (Iderawumi and Friday 2018). Species occurring during our own study belonged to the most common weed community in maize fields and competed strongly with it (Hossain *et al.* 2019).

Weeds in maize can be controlled by cultural, biological, mechanical and chemical methods (Rastgordani *et al.* 2013). Mechanical weed control is possible primarily in plants sown in wide rows, where weeders are used, including those equipped with cameras attached to a computer, which provide intra-row weed control without damaging the crops (Peruzzi *et al.* 2017). Weeds between the rows can normally be controlled by inter-row cultivation, such as hoeing. However, weeds growing within a line of row crop plants are not controlled and have a great influence on maize yield (Malander *et al.* 2012). Study results confirmed that total weed control in maize (weed free treatment) as a result of the of absence of any competition from weeds, favours its higher yield. In contrast, weeds left after mechanical weeding decreased the corncob yield through extremely low weed control. In spite of this, mechanical methods are basic for weed control in organic farming.

Effective weed control in maize is currently based solely on herbicides, that must both effectively control weeds, and be safe for crops (Waligóra *et al.* 2012). Application of herbicides containing at least two active ingredients with different sites of action, leads to control over a wide range of weed species, limits crop damages by usage of lower rates of herbicides, reduces the residues in plants and soil, delays the appearance of resistant weed species, and, finally, reduces plant protection costs (Idziak and Woznica 2020). The effectiveness of soil applied herbicides is reduced when applied to weeds developed under conditions of water deficiency due to low absorption and translocation of the active substances (Zanatta *et al.* 2008). On the other hand, excessive precipitation after herbicide application can transport the active substance beyond the weed germination zone, into the sphere of maize seed germination, and damage it (Soukup *et al.* 2004). The results of our study show that all herbicides were safe for sweet corn variety Hardi. Some researchers (Santel 2012) feel that this is due to the presence of sefener in the herbicide formulation. In the 3 years herbicide efficacy was quite similar and high, even though there were differences between herbicides and weed species, for example GERPU and POLCO. Due to the high efficacy (total weed control above 93%) and stability in the 3 years, the mixture T + M + S, was the most effective. Hand weeding (weed free treatment) was the most effective method, unlike mechanical weeding (hoeing twice), which was highly ineffective. Moreover, non-chemical weed control in crops is the most expensive, but not the most effective (Deese 2010), as confirmed by the weed management and net return indices from our study.

Conclusions

Due to weed infestation the corncob yield of sweet corn was reduced by 30% (under weather conditions favourable to maize development) and up to 93% (under favourable weather conditions). In sweet corn, weeds can be effectively managed by both preemergence or postemergence application of herbicides. However, findings showed that of the different herbicide treatments, a mixture of T + M + S applied postemergence gave slightly better results in terms of efficacy, weed management indices, yield and net return. Hand weeding can be an alternative to the chemical method because of its great effectiveness, but it is very labour consuming and it is usually practiced in small scale crop production similar to mechanical weeding.

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