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EFFECT OF STRIP TILLAGE AND MECHANICAL WEEDING ON YIELD OF SILAGE MAIZE PLANTED AFTER WINTER COVER CROP

Summary

A field experiment was conducted in 2012 to 2013 to determine the effect of tillage, including deep strip tillage, shallow strip tillage and conventional tillage, and weed control method (untreated control, mechanical, chemical) on growth and yield of maize planted after winter rye cover crop. Strip tillage was executed with the use of a universal active tool for the strip tillage and mechanical inter-row cultivation. Cultivated strips were 25 cm wide and 20cm deep at deep strip tillage, and 25 cm wide and 3-5 cm deep at shallow strip tillage. Conventional tillage was performed with moldboard plow at a depth of 20cm. Strip tillage provided maize yield similar to that of conventional tillage. Yields obtained after mechanical end chemical weed control were similar and significantly higher than at untreated control. The new developed active tool for the strip tillage and mechanical weeding provides good conditions for planting and growth of maize planted after winter rye cover crop.
Key words*: strip tillage, maize, mechanical weeding, winter cover crop*

WPŁYW PASOWEJ UPRAWY ROLI I MECHANICZNEGO ZWALCZANIA CHWASTÓW NA PLONOWANIE KUKURYDZY UPRAWIANEJ W PLONIE WTÓRYM

Streszczenie

Doświadczenie polowe przeprowadzono w latach 2012-2013 w celu określenia wpływu sposobu uprawy roli, w tym uprawy tradycyjnej, głębokiej uprawy pasowej, płytkiej uprawy pasowej oraz sposobu zwalczania chwastów (kontrola bez zwalczania, mechaniczne, chemiczne) na wzrost i plonowanie kukurydzy uprawianej w plonie wtórym po życie na zielonkę. Pasową uprawę roli wykonano uniwersalnym narzędziem uprawowo pielęgnacyjnym. Uprawiane pasy miały 25 cm szerokości oraz 20cm głębokości w przypadku głębokiej uprawy pasowej, natomiast w wersji płytkiej głębokość wynosiła 3-5 cm. Tradycyjną uprawę roli wykonano pługiem odkładnicowym na głębokość 20 cm. Po pasowej uprawie roli uzyskano plony zbliżone do plonów na obiektach z uprawą tradycyjną. Plony kukurydzy uzyskane na obiektach odchwaszczanych mechanicznie i chemicznie nie różniły się od siebie i były istotnie wyższe od uzyskanych na nieodchwaszczanych obiektach kontrolnych. Nowo skonstruowane uniwersalne narzędzie do uprawy pasowej i pielęgnacji międzyrzędowej zapewniło dobre warunki do wzrostu i plonowania kukurydzy uprawianej po międzyplonie ozimym.
Słowa kluczowe*: pasowa uprawa roli, kukurydza, pielenie mechaniczne, międzyplon ozimy*

1. Introduction

Double-cropping of silage maize with winter rye cover crop have the potential to generate additional forage for livestock and mitigate some of the environmental concerns associated with maize silage production [2, 3]. However late planting date of maize and reduced soil water storage reduces maize yield [2, 9]. Conventional tillage involving moldboard plowing and secondary tillage, is time and labor consuming. Intensive tillage accelerates soil drying, delay planting and increase the risk of soil erosion. Reduced tillage, especially no till, gives an opportunity to establish the maize crop just after rye harvest and residues remaining on the soil surface have the potential to conserve moisture and control of erosion. However planting maize into untilled soil can reduce maize crop emergence and slow plant development, resulting in lower yield [1, 4, 5, 7]. Strip tillage is an attractive compromise between no till and conventional tillage production system. Strip tillage creates a narrow zone for planting in which soil is cleaned from residues and tilled to prepare seedbed and allow for more even crop emergence [1, 7]. This system is widely spread in North America, but seldom applied in Poland and other European Countries. Strip tillage designs are typically based on a tine and disc combination with some residue managers and rollers [6]. Most of maize is planted into previous crop residues. Strip tilling into living stubble is much more difficult. To achieve good soil preparation in difficult conditions, an active tool for the strip tillage and mechanical inter-row cultivation, was developed at Industrial Institute of Agricultural Engineering in Poznań [8, 10].

The objectives of this study were to evaluate effect of strip tillage and mechanical weeding on yield of silage maize planted after winter cover crop.

2. Materials and methods

The field study was conducted during 2012 and 2013 on private farm in Duszniki Wielkopolskie, near Poznań, on a soil classified as Albic Luvisols developed on loamy sands overlying loamy material. The experiment was a random complete block with a split-plot arrangement and with four replications. Main plots consisted of three tillage systems including conventional tillage, deep strip tillage and shallow strip tillage. Subplots consisted of three weed management systems including untreated control, mechanical weed control and chemical weed control. Plot size was 3m (four rows with a 0.75 m row spacing) by 10 m.

Winter rye for haylage was mowed at boot stage and baled after one day of drying. Conventional tillage was conducted with the moldboard plow with furrow press at depth of about 20cm and spring harrow with rolling baskets at about 5cm. Strip tillage was executed with the use of a universal active tool for the strip tillage and mechanical inter-row cultivation, equipped with the universal load-bearing frame. The tool consisted of tines, rotary hoe, and roller. Tine loosens soil in row deep to about 20cm, rotary hoe makes strips 25 cm wide and 3-5 cm deep, roller reconsolidates soil for good seedbed. tines were removed from frame for shallow strip tillage and only 5 cm of soil was tilled with rotary hoe. Maize (Zea mays L. cv. Bejm) was planted at density of 10 seed·m^{-2}, in separate strip, with disk planter. Weeds were controlled, when maize was at 4 leafs stage, by spraying with 0.15 kg·ha^{-1} Maister 310WG (foramsulfuron + jodosulfuron) with 2 l·ha^{-1} Actirob 842 EC (adjuvant) at chemical control treatment. Mechanical weeding was carried out with the use of universal tool equipped with rotary hoe and weed harrow. Rotary hoe cultivated soil between rows and weed harrow worked in rows.

Maize was harvested by hand, from two center row, separately cobs and stover. Plants and cobs were counted and chopped. Samples, about 0.5 kg, were dried for dry mass content. Dry matter yield and cob content were determined.

Table 1. Weather conditions from March to September 2012 and 2013, and multiyear average

Tabela 1. Warunki pogodowe w okresie od marca do września 2012 i 2013 roku na tle wielolecia

Month *Miesiąc*	Year / *Rok* 2012	2013	Mean for 1961-2011 *Średnia z lat 1961-2011*
Precipitation; *Opady* (mm)			
March / *Marzec*	20.0	12.0	40.1
April / *Kwiecień*	22.9	15.4	37.6
May / *Maj*	77.2	69.8	56.9
June / *Czerwiec*	163.0	125.3	61.6
July / *Lipiec*	197.6	67.3	79.4
August / *Sierpień*	60.1	51.5	66.9
September / *Wrzesień*	30.0	33.7	49.7
Total / *Suma*	570.8	375.0	392.2
Temperature;*Temperatura* (°C)			
March / *Marzec*	5.7	-2.5	2.9
April / *Kwiecień*	8.8	8.0	8.0
May / *Maj*	14.8	14.4	13.2
June / *Czerwiec*	16.0	17.3	16.6
July / *Lipiec*	19.2	20.1	18.2
August / *Sierpień*	18.7	19.1	17.5
September / *Wrzesień*	14.3	12.9	13.3
Mean / *Średnia*	13.9	12.8	12.8

Source: own work / *Źródło*: praca własna

Data were analyzed by analysis of variance and means were compared using Tuckey's LSD test at the $P \leq 0.05$ probability level.

The weather conditions during the spring vegetation of rye were optimal for growth in both years (Table 1). Dry April promoted deep rooting and was followed with high precipitation at beginning of May, optimal for biomass production. Dry and warm weather at harvest of rye haylage and planting of maize was also favorable for this operations. Weather conditions were more favorable to the development of maize in 2013 than in 2012. Total precipitation was greater in 2012, but most of it occurred at last week of June and first week of July. Most of June and second half of July were dry and hot. Precipitation in 2013 was below average but was more evenly distributed.

3. Results and Discussion

Plant population was significantly affected by tillage in 2012 (Table 2). Maize population was less in deep strip till, with only 7.28 plant·m^{-2}, than in shallow strip till and conventional tillage (9.48 and 9.44 plant·m^{-2}, respectively). In 2013 reduced corn population in conventional tillage was observed at weedy control and mechanical weeding plots but no differences between tillage systems occurred in chemical weed control system. Reduced tillage, especially no till, often creates seedbed less favorable for planting, germination and emergence of corn and reduces crop establishment [1, 6, 7]. Strip tillage is a compromise between no-till and conventional tillage, creates a cultivated zone for planting and crop growth and allows for more even crop emergence than no-till [1, 7]. However, living stubble of haylage rye makes strip tilling much more difficult. The new active tool, tested in study, allowed to obtain satisfactory crop emergence. Mechanical weed control, made when maize was at 4 leafs stage, was safe for young plants, no plant loss was observed, in comparison with untreated control.

Table 2. Plant population depending on tillage method and weed control (No·m^{-2})

Tabela 2. Obsada roślin, w zależności od sposobu uprawy roli i zwalczania chwastów (szt·m^{-2})

Tillage (A) *Uprawa roli*	Weed control (B) *Zwaczanie chwastów*: Untreated *Kontrola*	Mechanical *Mechaniczne*	Chemical *Chemiczne*	Mean *Średnia*
2012				
Conventional tillage *Uprawa tradycyjna*	9.83	9.67	8.83	9.44
Strip tillage – deep *Uprawa pasowa głęboka*	7.38	7.16	7.28	7.28
Strip tillage – shallow *Uprawa pasowa płytka*	9.72	9.33	9.39	9.48
Mean *Średnio*	8.98	8.72	8.50	
$LSD_{0,05}$; $NIR_{0,05}$; A=1.10; B=ns; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	7.78	8.05	8.91	8.25
Strip tillage – deep *Uprawa pasowa głęboka*	8.56	8.90	8.52	8.66
Strip tillage – shallow *Uprawa pasowa płytka*	8.75	8.85	8.97	8.86
Mean / *Średnio*	8.37	8.60	8.80	
$LSD_{0,05}$; $NIR_{0,05}$; A=0.47; B=0.30; B/A=0.52; A/B=0.63				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 3. Number of cobs per plant depending on tillage method and weed control

Tabela 3. Liczba kolb na roślinie, w zależności od sposobu uprawy roli i zwalczania chwastów

Tillage (A) *Uprawa roli*	Weed control (B) *Zwaczanie chwastów*			Mean *Średnia*
	Untreated; *Kontrola*	Mechanical; *Mechaniczne*	Chemical; *Chemiczne*	
2012				
Conventional tillage *Uprawa tradycyjna*	0.98	0.85	0.98	0.93
Strip tillage – deep *Uprawa pasowa głęboka*	1.10	0.95	1.18	1.08
Strip tillage – shallow *Uprawa pasowa płytka*	1.10	1.00	1.35	1.15
Mean *Średnio*	1.06	0.93	1.17	
$LSD_{0.05}$; $NIR_{0,05}$; A=0.21; B=0.22; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	1.03	1.15	0.98	1.05
Strip tillage – deep *Uprawa pasowa głęboka*	1.00	0.96	0.95	0.98
Strip tillage – shallow *Uprawa pasowa płytka*	1.03	0.98	1.00	1.00
Mean *Średnio*	1.02	1.03	0.98	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Number of cobs on plant was lower in conventional tillage than in shallow strip till plots in first year of study (Table 3). Number of cobs was also negatively affected by mechanical weed control in comparison with chemical weeding. Tillage and weed control systems did not influence this parameter in 2013.

Yield of silage dry biomass was greater in shallow strip tillage than in conventional tillage in 2012, and the trend remained in 2013 (Table 4). Yield of maize after deep strip tillage did not statistically differ from conventional tillage in both years but tended to be slightly bigger after strip tillage. There were no differences in yield between mechanical and chemical weed control systems but significant yield loss was observed at untreated control. Experimental factors did not affect relative contribution of cob to the whole yield of dry matter (Table 7). Therefore, the effect of studied factors on the yield of cobs and yield of stover was similar to the effect on the total yield of dry matter (Table 5 and 6).

Yield of plant is created by many factors, one of them is proper tillage and weed control. Reduced tillage often reduces final yield of corn grain or silage [1, 4, 5, 7]. After strip tilling with tested active tool for the strip tillage and mechanical weed control, yields were at least the same as obtained at conventionally tilled plots. This indicates that this tool is suitable to difficult conditions of living rye stubble.

Table 4. Yield of whole-crop (dry matter) depending on tillage method and weed control ($t \cdot ha^{-1}$)

Tabela 4. Plon ogólny suchej masy w zależności od sposobu uprawy roli i zwalczania chwastów($t \cdot ha^{-1}$)

Tillage (A) *Uprawa roli*	Weed control (B) *Zwaczanie chwastów*			Mean *Średnia*
	Untreated *Kontrola*	Mechanical *Mechaniczne*	Chemical *Chemiczne*	
2012				
Conventional tillage *Uprawa tradycyjna*	10.95	15.40	13.66	13.34
Strip tillage – deep *Uprawa pasowa głęboka*	11.26	16.78	15.30	14.44
Strip tillage – shallow *Uprawa pasowa płytka*	17.19	18.73	21.83	19.25
Mean *Średnio*	13.13	16.97	16.93	
$LSD_{0.05}$; $NIR_{0,05}$; A=4.86; B=3.23; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	12.3	20.9	19.3	17.5
Strip tillage – deep *Uprawa pasowa głęboka*	15.1	21.2	19.3	18.5
Strip tillage – shallow *Uprawa pasowa płytka*	15.1	21.3	20.2	18.9
Mean *Średnio*	14.2	21.1	19.6	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=2.7; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 5. Yield of stover (dry matter depending on tillage method and weed control ($t \cdot ha^{-1}$)

Tabela 5. Plon suchej masy łodyg i liści, w zależności od sposobu uprawy roli i zwalczania chwastów ($t \cdot ha^{-1}$)

Tillage (A) *Uprawa roli*	Weed control (B) *Zwaczanie chwastów*			Mean *Średnia*
	Untreated; *Kontrola*	Mechanical; *Mechaniczne*	Chemical; *Chemiczne*	
2012				
Conventional tillage *Uprawa tradycyjna*	7.19	10.55	8.70	8.81
Strip tillage – deep *Uprawa pasowa głęboka*	7.07	10.58	9.20	8.95
Strip tillage – shallow *Uprawa pasowa płytka*	10.70	12.15	12.41	11.75
Mean *Średnio*	8.32	11.09	10.10	-
$LSD_{0.05}$; $NIR_{0,05}$; A=2.63; B=2.06; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	4.86	7.71	7.46	6.68
Strip tillage – deep *Uprawa pasowa głęboka*	6.05	8.54	7.67	7.42
Strip tillage – shallow *Uprawa pasowa płytka*	6.11	8.66	7.96	7.58
Mean *Średnio*	5.67	8.31	7.70	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=1.08; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 6. Yield of cobs (dry matter) depending on tillage method and weed control (t·ha^{-1})

Tabela 6. Plon suchej masy kolb, w zależności od sposobu uprawy roli i zwalczania chwastów (t·ha^{-1})

Tillage (A) *Uprawa roli*	Weed control (B) / *Zwaczanie chwastów*			Mean *Średnia*
	Untreated *Kontrola*	Mechanical *Mechaniczne*	Chemical *Chemiczne*	
2012				
Conventional tillage *Uprawa tradycyjna*	3.76	4.86	4.96	4.53
Strip tillage – deep *Uprawa pasowa głęboka*	4.18	6.20	6.10	5.50
Strip tillage – shallow *Uprawa pasowa płytka*	6.49	6.58	9.42	7.49
Mean / *Średnio*	4.81	5.88	6.83	
$LSD_{0.05}$; $NIR_{0,05}$; A=2.43; B=1.36; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	7.43	13.14	11.87	10.81
Strip tillage – deep *Uprawa pasowa głęboka*	9.04	12.66	11.65	11.12
Strip tillage – shallow *Uprawa pasowa płytka*	9.04	12.63	12.19	11.29
Mean / *Średnio*	8.50	12.81	11.90	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=2.22; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 7. Cob content in dry matter yield depending on tillage method and weed control (%)

Tabela 7. Udział kolb w plonie suchej masy, w zależności od sposobu uprawy roli i zwalczania chwastów (%)

Tillage (A) *Uprawa roli*	Weed control (B) *Zwaczanie chwastów*			Mean *Średnia*
	Untreated *Kontrola*	Mechanical *Mechaniczne*	Chemical *Chemiczne*	
2012				
Conventional tillage *Uprawa tradycyjna*	32.9	32.3	35.8	33.7
Strip tillage – deep *Uprawa pasowa głęboka*	36.7	36.7	40.1	37.9
Strip tillage – shallow *Uprawa pasowa płytka*	37.8	35.2	42.8	38.6
Mean / *Średnio*	35.8	34.7	39.5	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=3.6; B/A=ns; A/B=ns				
2013				
Conventional tillage *Uprawa tradycyjna*	60.0	62.8	61.0	61.3
Strip tillage – deep *Uprawa pasowa głęboka*	59.9	59.7	60.1	59.9
Strip tillage – shallow *Uprawa pasowa płytka*	59.6	59.3	60.3	59.8
Mean / *Średnio*	59.8	60.6	60.5	
$LSD_{0.05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

4. Conclusions

1. Strip tillage provided yield of silage, cobs and stover similar to obtained after conventional tillage.

2. Weed control, regardless of the method, significantly increased the yield of maize.

3. The new developed active tool for the strip tillage and mechanical inter-row cultivation provides good conditions for planting and growth of maize planted after winter rye cover crop.

5. References

[1] Hendrix B.J., Young B. G., Chong S.: Weed management in strip tillage corn. Agron. J., 2004, 96, 229-235.

[2] Krueger E., Ochsner T., Porter P., Baker J.: Winter rye cover crop management influences on soil water, soil nitrate and corn development. Agron. J., 2011, 103, 316-323.

[3] Krueger E., Ochsner T., Baker J., Porter P., Reicosky D.: Rye-corn silage double-cropping reduces corn yield but improves environmental impacts. Agron. J., 2012, 104, 888-896.

[4] Majchrzak L. Skrzypczak G., Pudełko J.: Wpływ uproszczeń w uprawie roli na plonowanie kukurydzy. Cz.I uprawa kukurydzy w plonie głównym. PTPN, prace komisji nauk rolniczych i komisji nauk leśnych, 2002, 93, 39-51.

[5] Majchrzak L. Skrzypczak G., Pudełko J.: Wpływ uproszczeń w uprawie roli na plonowanie kukurydzy. Cz.II uprawa kukurydzy w plonie wtórym. PTPN, prace komisji nauk rolniczych i komisji nauk leśnych, 2003, 95, 121-128.

[6] Morris N., Miller P., Orson J., Froud-Williams R.: The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment – A review. Soil Till. Res., 2010, 108,1-15.

[7] Piechota T.: Reakcja kukurydzy na pasową uprawę roli w warunkach niedoborów wody. Zesz. Probl. Post. Nauk Roln., 2011, 559, 153-160.

[8] Piechota T., Zbytek Z., Kowalski M., Dach J.: Wpływ pasowej uprawy roli i mechanicznego zwalczania chwastów na fizyczne właściwości gleby w uprawie kukurydzy w plonie wtórym. J. Res. Appl. Agric. Eng., 2013, 4, 104-108.

[9] Rüegg W., Richner W., Stamp P., Feil B.: Accumulation of dry matter and nitrogen by minimum-tillage silage maize planted into winter cover crop residues. Eur. J. Agron., 1998, 8, 59-69.

[10] Zbytek Z., Talarczyk W., Łowiński Ł.: Wpływ zastosowania różnych elementów roboczych na wytrzymałość konstrukcji uniwersalnej ramy nośnej maszyny rolniczej. Technika Rolnicza Ogrodnicza Leśna, 2013, 1, 28.

Universal tool for strip-tillage. Research project No. N N313 788940 supported by the Ministry of Science and Higher Education, Warsaw (Poland).