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RESPONSE OF CARROT (*Daucus carota* L.), TO STRIP TILLAGE AND INJECTION OF LIQUID SWINE MANURE INTO PLANT ROW

Summary

Field study was conducted between 2011 and 2012 to determine the effects of liquid manure injected into plant row just before planting carrot in strip tillage. Strip tillage machine consisted of four units attached to frame. Every unit included shank, covering discs and rolling basket. The applicator consisted of a plastic tank mounted on the top of frame, valve, delivery hoses and injection tubes installed just after shanks. Average tillage depth was 20 cm and injection one: 10 cm. Strip tillage was compared with mouldboard ploughing. The new technology was safe for carrot plants. Plant emergence and root quality were not affected by injection of swine manure into plant row. Yield of roots obtained after mineral and organic fertilization was similar. Results of the study show, that injection of liquid swine manure in strip tillage is possible in carrot production, but further studies are needed to optimize technology.
Key words: *strip tillage, carrot, liquid swine manure, manure injection*

REAKCJA MARCHWI (*Daucus carota* L.) NA PASOWĄ UPRAWĘ ROLI ORAZ WGŁĘBNĄ APLIKACJĘ GNOJOWICY W RZĘDZIE ROŚLIN

Streszczenie

W latach 2011-2012 przeprowadzono ścisłe doświadczenie polowe, w którym oceniano wpływ wgłębnej aplikacji gnojowicy, wykonanej bezpośrednio przed siewem, rzędowo, przy użyciu agregatu do pasowej uprawy roli na wzrost i plonowanie marchwi. Agregat składał się z czterech sekcji, zbudowanych z zęba, pary talerzy i wałka strunowego. Ze zbiornika nabudowanego na ramie agregatu nawozy organiczne były doprowadzane wężami do rur znajdujących się bezpośrednio za zębami. Uprawę roli wykonywano na głębokość 20 cm a aplikację nawozów na 10 cm. Pasową uprawę roli porównywano z tradycyjną uprawą płużną. Nowa technologia okazała się bezpieczna dla roślin marchwi. Nie stwierdzono wpływu doglebowej aplikacji gnojowicy w rzędzie na wschody roślin ani jakość korzeni spichrzowych. Plon korzeni uzyskany po nawożeniu świńską gnojowicą był zbliżony do uzyskanego po nawożeniu mineralnym. Wyniki przeprowadzonego doświadczenia świadczą, że w uprawie marchwi jest możliwe zastosowanie pasowej uprawy roli wraz z doglebową aplikacją gnojowicy w rzędzie roślin, jednakże konieczne są dalsze badania nad optymalizacją technologii.
Słowa kluczowe: *pasowa uprawa roli, marchew, świńska gnojowica, aplikacja doglebowa*

1. Introduction

Conventional tillage involving moldboard plowing and secondary tillage is time and labor consuming. Intensive tillage accelerates soil drying, delay planting and increases the risk of soil erosion. Reduced tillage especially no till, gives an opportunity to establish crop just after harvest. Residues remaining on the soil surface have the potential to conserve moisture and control of erosion. However planting into untilled soil can reduce crop emergence and slow plant development, resulting in lower yield [5, 8, 10]. 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 allows for more even crop emergence [5, 10, 12]. This system works well for wide row crops like maize, sugar beet, cotton and sunflower [5, 9, 10]. It combines benefits of intensive cultivation in crop row and no-till between rows. Strip till is widely spread in North America, especially in maize, 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 [5, 9].

Liquid swine manure (LSM) is good resource of plant nutrients but poor management can result in high air and water pollution, the poor response of crop or even plant injury. When LSM is surface broadcast high ammonia and odor emissions occur. Incorporation or injection reduces volatilization but requires additional tool, increased horsepower and application time [6]. Conservation tillage adds a new challenge to proper manure incorporation. Aggressive tools makes good job covering manure but reduces plant residue cover and result in higher levels of soil erosion and surface runoff.

Combining strip tillage with injection of LSM may give many advantages. Reduced ammonia volatilization, less odor, nutrients applied close to plants, undisturbed soil cover between rows but good seedbed in crop row, savings in time, labor and fuel and all of this may be achieved in one operation. So far, there were published only a few works about manure injection and strip tillage in maize [4, 12]. But there are also some concerns about crop injuries from LSM concentrated just under plants. High concentration of ammonia and salts combined with high oxygen demand may injure seedlings or inhibit root development [7]. It is especially dangerous for root crop, when not only quantity but also quality of yield is affected.

The objectives of this study were to evaluate how does carrot response to strip tillage and injection of liquid swine manure in plant row.

2. Materials and methods

The field study was conducted during 2011 and 2012 on private farm in Lubosz, near Poznań, on a soil classified as Albic Luvisols developed on loamy sands overlying loamy material. The experiment was a randomized complete block with a split-plot arrangement and with four replications. Main plots consisted of two tillage systems including conventional tillage and strip tillage. Subplots consisted of three fertilization systems: untreated control, mineral and liquid swine manure (LSM). Studies were established as cover crops after winter triticale. Four rows, plot-scale, strip tillage machine consisted of four units attached to frame. Every unit included coulter, shank, covering disks and rolling basket. Cultivated strips were 25cm wide and 20cm deep, row spacing was 45cm. The applicator consisted of a 1000 l plastic tank mounted on the top of frame, valve, four delivery hoses and injection tubes installed just after strip tiller shanks. Average injection depth was 10cm. On plots with conventional tillage, machine was mounted over ground and additional splash plates were added for uniform broadcast application. Conventional tillage was conducted with disc harrow just after LSM application, moldboard plow with furrow press at depth of about 20 cm and spring harrow with rolling baskets at about 5 cm. Mineral fertilizer was manually broadcasted at rate of 100 $kg \cdot ha^{-1}$ N, 35 kg P and 95 kg K. Rates of liquid swine manure (about $55 m^3 \cdot ha^{-1}$) were based on nitrogen content, to provide 170 $kg \cdot ha^{-1}$ of total N, which fertilizer replacement value corresponds to approximately 100 $kg \cdot ha^{-1}$ of N in mineral fertilizer.

Table 1. Weather conditions from July to October 2011 and 2012, and multiyear average

Tabela 1. Warunki pogodowe w okresie lipiec-październikw latach 2011 i 2012 na tle wielolecia

Month *Miesiąc*	Year; *Rok* 2011	Year; *Rok* 2012	Mean for 1961-2010 *Średnia z lat 1961-2010*
Precipitation; *Opady* (mm)			
July; *Lipiec*	175.4	197.6	79.4
August; *Sierpień*	34.5	60.1	66.9
September; *Wrzesień*	46.0	30.0	49.7
October; *Październik*	18.2	47.6	40.8
Total; *Suma*	274.1	335.3	236.8
Temperature;*Temperatura* (°C)			
July; *Lipiec*	17.9	19.2	18.2
August; *Sierpień*	18.8	18.7	17.5
September; *Wrzesień*	15.3	14.3	13.3
October; *Październik*	9.5	8.2	8.5
Mean; *Średnia*	15.4	15.1	14.4

Source: own work / *Źródło*: praca własna

Carrot (*Daucus carota* L. cv. Jerada F1) was planted at density of 80 $seed \cdot m^{-2}$, in separate strip, with hand push disk planter. Plots were 4 rows (180 cm) wide and 6 m long.

Carrot was harvested by hand, from two center rows. Roots were counted and weighed. Root length and root injuries and defects were assessed on 30 plants per plot. Index of root injury was calculated as:

$$Index = [0(a) + 10(b) + 30(c) + 60(d) + 100(e)]/T,$$

when:
a = number of plants with 0% injuries or defects,
b = 1-10%,
c = 11-30%,
d = 31-60%,
e = 61-100%,
T = total number of plants in sample.

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

Unusually high precipitation in July delayed harvest of triticale and planting of carrots to second decade of August, both years (Table 1). The weather conditions during the vegetation of carrot were favorable for growth at both years. Total precipitation was greater than multiyear average. Temperatures were also over average, except July 2011 and October 2012 which were lower by 0.3°C than multiyear average.

3. Results and Discussion

Plant population was not significantly affected by tillage and fertilization, but differed between years (Table 2). Carrot population was less in 2012, with only 50.8 $plant \cdot m^{-2}$, than in 2011 (72.1 $plant \cdot m^{-2}$). Reduced tillage, especially no till, often creates seedbed less favorable for planting, germination and emergence of plants and reduces crop establishment [5, 9, 10]. However, properly managed plant residues, cover crops and reduced tillage implements, adequate to local soil and climate conditions and cropping systems can provide crop density similar to conventional tillage plots, or even improve plant emergence [1, 2]. 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 [5, 10, 12] and similar to conventional tillage [3]. Plant emergence and growth may be also negatively affected by manure over-application or fertilizer placement method providing local over-concentration near seedlings [4, 7]. It is especially dangerous for root crop, when not only quantity but also quality of yield is affected. However there was no evidence, from the study, that the injection of LSM to carrot row increased root injuries. Most root injuries and defects were due to forking but forks were small and not influenced root market quality in most cases. Index of root injury was at very low level, did not extended 1.8, and was not affected by tillage method or fertilization (Table 3). In first year of experiment, on strip till plots, carrot roots were significantly longer after mineral or LSM fertilization relative to untreated control (Table 4). Fertilization had no significant impact on root length on conventional tillage plots. Strip till promoted deep root growth after LSM application, roots were 0.99 cm longer than in conventional tillage. Neither tillage nor fertilization influenced the root length in 2012. However roots in strip till tended to be longer than in conventional tillage. It indicates that injection of high volume of LSM into plant row, did not inhibit root growth.

Root yield of carrot was very low, mostly due to summer rains and delayed planting (Table 5). Regardless of tillage, mineral fertilization and manuring with LSM has positive impact on root yield. Type of fertilizer (mineral, LSM) did not differentiate yield, both years of experiment. In 2011 root yield was influenced by the interaction between soil tillage and fertilization. In terms of mineral fertilization yield was higher in conventional tillage compared with strip till. However, tillage had no effect on root yields of carrot fertilized with manure or without fertilization. In 2012 yield

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

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

Tillage (A) *Uprawa roli*	Fertilization (B) *Nawożenie*			Mean *Średnia*
	Untreated *Kontrola*	Mineral *Mineralne*	Manure *gnojowica*	
2011				
Conventional tillage *Uprawa tradycyjna*	68.5	69.8	76.9	71.7
Strip tillage *Uprawa pasowa*	73.3	72.0	72.0	72.5
Mean *Średnio*	70.9	70.9	74.4	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				
2012				
Conventional tillage *Uprawa tradycyjna*	55.9	51.5	51.1	52.8
Strip tillage *Uprawa pasowa*	48.5	48.9	48.9	48.6
Mean *Średnio*	52.2	50.2	50.0	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 3. Index of root injury depending on tillage method and fertilization (0-100)

Tabela 3. Indeks uszkodzeń korzeni, w zależności od sposobu uprawy roli i nawożenia (0-100)

Tillage (A) *Uprawa roli*	Fertilization (B) *Nawożenie*			Mean *Średnia*
	Untreated; *Kontrola*	Mineral; *Mineralne*	Manure; *gnojowica*	
2011				
Conventional tillage *Uprawa tradycyjna*	0.25	0.92	0.92	0.69
Strip tillage *Uprawa pasowa*	1.58	1.92	1.17	1.56
Mean *Średnio*	0.91	1.42	1.04	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				
2012				
Conventional tillage *Uprawa tradycyjna*	1.00	0.50	1.75	1.08
Strip tillage *Uprawa pasowa*	1.50	1.00	1.25	1.25
Mean *Średnio*	1.25	0.75	1.50	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 4. Root length depending on tillage method and fertilization (cm)

Tabela 4. Długość korzenia spichrzowego marchwi w zależności od sposobu uprawy roli i nawożenia (cm)

Tillage (A) *Uprawa roli*	Fertilization (B) *Nawożenie*			Mean *Średnia*
	Untreated *Kontrola*	Mineral *Mineralne*	Manure *gnojowica*	
2011				
Conventional tillage *Uprawa tradycyjna*	9.99	10.96	10.46	10.47
Strip tillage *Uprawa pasowa*	9.18	11.36	11.45	10.67
Mean *Średnio*	9.59	11.16	10.95	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=0.85; B/A=1.21; A/B=0.88				
2012				
Conventional tillage *Uprawa tradycyjna*	9.82	8.98	8.61	9.13
Strip tillage *Uprawa pasowa*	10.57	9.78	9.99	10.11
Mean *Średnio*	10.19	9.38	9.30	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=ns; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna

Table 5. Yield of roots depending on tillage method and fertilization (t·ha^{-1})

Tabela 5. Plon korzeni, w zależności od sposobu uprawy roli i nawożenia (t·ha^{-1})

Tillage (A) *Uprawa roli*	Fertilization (B) *Nawożenie*			Mean *Średnia*
	Untreated *Kontrola*	Mineral *Mineralne*	Manure *gnojowica*	
2011				
Conventional tillage *Uprawa tradycyjna*	2.75	7.57	6.20	5.51
Strip tillage *Uprawa pasowa*	2.46	4.26	6.43	4.38
Mean *Średnio*	2.61	5.92	6.32	
$LSD_{0,05}$; $NIR_{0,05}$; A=ns; B=1.38; B/A=1,95; A/B=1,96				
2012				
Conventional tillage *Uprawa tradycyjna*	4.57	5.59	5.51	5.22
Strip tillage *Uprawa pasowa*	2.98	4.89	4.92	4.27
Mean *Średnio*	3.78	5.24	5.22	
$LSD_{0,05}$; $NIR_{0,05}$; A=0.54; B=0.65; B/A=ns; A/B=ns				

ns– not significant difference – *różnica nieistotna*

Source: own work / *Źródło*: praca własna after strip till was significantly lower than after conventional tillage. The yields at mineral fertilizer and LSM treatments were similar but significantly bigger than at unfertilized control. Yield of plant is created by many factors. Reduced tillage often reduces final yield [5, 8, 10] but proper fertilization can improve yields [4, 11]. Results of this study prove that injection of LSM in one operation with strip tillage is possible in carrot production. This gives many agronomical, economical and environmental advantages. However further studies are needed to optimize new technology, for efficient use of LSM in strip till of carrot and other root crops in varied agronomical and natural conditions.

4. Conclusions

1. Plant emergence, index of root injuries and root length were not negatively affected by injection of LSM into plant row.
2. Yield of roots obtained after mineral and organic fertilization was similar and significantly higher than at untreated control.
3. Results of the study show, that soil injection of liquid swine manure in one operation with strip tillage is possible in carrot production. However further studies are needed to optimize new technology for efficient use of LSM with strip tillage in carrot and other root crops.

5. References

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