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The effect of direct seeding on the soil resistance and the silage corn yield

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ABSTRACT

Purpose: The paper compares the effect of five different direct seeding methods to the conventional tillage on the emerging and yield of silage corn (Zea may L.) in two different pedo-ecological conditions of Slovenia.
Design/methodology/approach: A randomly selected 4x6 block designed field test was carried out; gliphosat treatment 1 week before seeding (V1), mowing+focus ultra on the whole plot 3 weeks later (V2), mowing+focus ultra in bands 3 weeks later (V3), mowing+focus ultra in bands 3 weeks later+mowing the inter-row after emergence (V4), conventional tillage (V5), focus ultra on the whole plot 3 weeks after seeding (V6).
Findings: The highest emergence was on parcels with treatment V5; 98.99 % in Noršinci and 82.75 % in Pohorski dvor. The (V1) treatment influenced lowest emergence in Noršinci (82.48 %) and Pohorski dvor (63.25 %). The number of emerged seedlings affected the highest yield of fresh silage on V5 (50.590 kg ha-1 - Nošinci and 45.661 kg ha-1 - Pohorski dvor) and dry matter (20.228 kg/ha). However, there was no difference to V1 and V4. The penetrometer measurements showed the highest soil resistance (119.78 N cm-2) in Noršinci on V3 and (185.31 N cm-2) in Pohorski dvor on V4.
Research limitations/implications: The experiment presented herein can be applied under similar pedo-climatical condition.
Practical implications: Alternative seeding methods can reduce the fuel consumption and CO_2 emission by decreasing the number of passes on the field.
Originality/value: By implementing the findings from our experiments a high intensity of soil engagement and inversion of the soil by using of mouldboard plough can be omitted on the majority of sandy and silty-loam soils. On that way the energy saving-method can make an effective contribution to farmers' economy.
Keywords: Technological devices and equipment; Direct seeding; Conventional tillage; Silage corn; Dry matter yield; Soil penetration resistance

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1. Introduction

Tillage is on of the highest power-required processes in the agricultural production. The high cost of energy forces farmers to find alternative economic tillage systems. It is clearly recognized that the application of the energy saving methods can make effective contribution to economy [1, 3].

In arable crops growing soil tillage operations require 75% of the total energy spent before the seed-time [14] and sowing by different pneumatic i. e. planters less than 3% [12, 13].

A conventional tillage system is based on a high intensity of the soil engagement and inversion of the soil with mould board plough. Contrary, the conservation tillage systems try to disturb the soil as little as possible to conserve its natural structure, leave the maximum vegetal residue next to the soil surface and build a rough surface. Typical machines are hereby chisels and wing-tine cultivators [17].

Silage corn represents the third most grown crop after winter wheat and grain corn in Slovenia [15]. The conventional method of preparing the seedbed based on mould board plough and rotary tiller in four-year rotation after the perennial ryegrass (*Lolium perenne L.)*, which follows the winter wheat and corn. However, this method has got excessive field traffic and high energy cost.

Linden et al [10] compared conventional tillage with reduced tillage and no-tillage methods. In first 5 years, there was no significant difference between the methods, however in the sixth year the yield was reduced in no-tillage method.

Reduced and no-tillage systems were successfully tested in different crops in the USA [4]. Diaz-Zorita and Muršec et al [7, 11] showed that the seedbed preparation using either mould board or chisel plough with or without deep tillage increase the corn yield when compared to the no-tillage systems. On the other hand, Carter et al [5] reported that corn yield was not consistently influenced by the tillage or rotation treatment.

No-till corn production yields only 4 % less in comparison to conventional tillage method, but on the other side no-till can assure up to 82.6 % production costs saving and improvement of soil microbiological activity [9, 18].

On the other hand, whenever the use of conservative and conventional tillage was compared in the sub alp climatically condition in Jable (Slovenia) with the average of 1348 mm annual precipitation in the period of 1999-2002, the average yield of four-year rotation (corn-barley-pea-winter wheat) exceeded over the conservative tillage for 8.3-40.0 % depending on the particular crop [16]. Contrary, in the two-year rotation (corn-winter wheat) the yield of corn was for 9.3% and the winter wheat for 13% higher.

When the farmers change to no-tillage system a decreasing yield is noticed. However, the decrease in yield is generally economically greater than the savings obtainable by the reduction in tillage intensity; no-tillage management is also more difficult because of weed control and requires more technical knowledge [2]. Furthermore, yields are not steadily uniform and vary in relation to climatic conditions.

The main goal of this research was to compare different direct seeding methods with conventional soil tillage, which is based on mould board plough and rotary harrow. New direct seeding procedures involved mowing of perennial ryegrass and herbicide application in production of silage corn, which may replace the conventional soil preparation.

Our second intention was to examine the impact of the direct seeding on the compactness of the upper 50 cm layer of soils, due to the reduction of four passes with the tractor on the field by the new method.

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

The sowing of corn (*Zea mays* L.*)* was performed with a four-row Monosem NX pneumatic planter (Fig. 1) for direct and conventional seeding with precise seed and fertilizer metering units. The experiment was conducted during the growing season 2007 on two locations (Table 1) with different but the most frequent soil types in the Eastern Slovenia.

Fig. 1. Direct seeding with a Monosem MX planter

Table 1.
Locations of experiment, soil types and textures[a]

	Noršinci	Pohorski dvor
Position	46°40'N, 16°12'E	46°30'N, 15°37'E
Soil type	Calcaric Gleysol	Dystric Cambisol
Soil texture	silty loam	silty clay
Clay	22.60 %	34.28 %
Silt	28.00 %	44.36 %
Sand	42.90 %	21.36 %

In both experimental fields a silage corn was a part of a four-year rotation (corn - winter-wheat - perennial grass - silage corn), which is commonly applied in the Slovenian arable land production.

The corn used was Unixx Duo hybrid for silage, which was resistant to focus ultra herbicide (Herbocid). As seen from Table 1, there were two types of soils according to FAO classification involved in the experiment; a silty loam in Noršinci and silty clay on Pohorski dvor, both well drained.

On both locations a randomized block design with four blocks (Table 2) was used for statistical analysis of the experiment.

Each treatment represents the 2.80 m wide and 30 m long parcel. The seeding rate was 100.000 seeds ha^{-1} with 70 cm row width and 6 cm planting depth.

Table 2.
Block design of the field experiment

I.	V6	V2	V3	V1	V5
II.	V4	V1	V2	V6	V5
III.	V3	V6	V4	V2	V5
IV.	V2	V4	V1	V3	V5
V.	V1	V3	V6	V4	V5

I., II., III., IV., V..… blocks, V1 to V6 ………. treatment

After mowing perennial ryegrass from the filed, the following six tillage methods of preparing the soil and seeding were compared:

- gliphosat treatment 1 week before seeding (V1),
- mowing + focus ultra on the whole plot 3 weeks after seeding (V2),
- mowing + focus ultra in bands 3 weeks after seeding (V3),
- mowing + focus ultra in bands 3 weeks after seeding + mowing the inter row space after emergence (V4),
- conventional tillage (V5),
- focus ultra on the whole plot 3 weeks after seeding (V6).

As seen from Table 3 outlining a series of field operations necessary for each treatment, different equipment was used during the field experiment.

Table 3.
Field operations and applied implements during different treatments

Tillage system	Operation	Implement
V5	Ploughing	Mouldboard plough
	Soil preparation	Rotary harrow
	Sowing and fertilization	Pneumatic planter
V1, V6	Herbicide spraying	Boom sprayer
	Sowing and fertilization	Pneumatic planter
V2, V3, V4	Mowing	Rotary mower
	Soil preparation	Chisel plough
	Sowing and fertilization	Pneumatic planter

The percentage of emerged seedlings (PE) was measured in the filed on May 1[st] and later calculated in the laboratory using the equations (1) developed by Bilbro et al [3]:

$$PE = \left(\frac{total\ \ emerged\ \ seeding\ \ per\ \ meter}{number\ \ of\ \ seeds\ \ planted\ \ per\ \ meter} \right)\ x\ 100 \qquad (1)$$

The basic fertilization was done instantly at the seeding by applying of a 350 kg ha^{-1} dosage of NPK (15:15:15). The second dressing fertilization was performed on May 17th 2007 in the stage of three leaves by adding a dosage of 300 kg ha^{-1} KAN (27).

To measure the effect of different tillage on the soil characteristics, the soil penetration resistance was measured by a hydraulic penetrometer (Biotechnical Faculty, Department of Agronomy, Ljubljana, Slovenia). Composed of a basic framework, hydraulic system, measurement sensors and measuring equipment, it contains a special slide on top of the framework, enabling the movement of a two-way hydraulic cylinder, to which a cone with a tip of 30° and a surface of 1.29 cm^2 is attached (Fig. 2) In conformity with the ASAE S313.1 Standard [6].

Fig. 2. Measuring of soil resistance with penetrometre

Measurements were carried out prior seeding on April 18[th] 2007 and after harvesting on September 29[th] 2007 by taking six sample points from each parcel. At each measuring point, the cone tip was shifted close to the soil surface by means of a lever. The computer program for the measurement of cone resistance was then started up and the penetrometer cone tip was pushed into the soil. A continuously variable measurement of the cone resistance was carried out down to a depth of 50 cm. The measured force [N] and shift values [cm] were separately stored to a specified file. The average of 5 cm layers and, finally, the total average of 50 cm were calculated with a software package LabView 6.0.

When the average dry matter content of the grain was higher than 42 %, a 10 m^2 sample of whole plants were harvested manually and weighed on the electronic weighing machine. The precise dry matter content was later detected in laboratory, after the samples of plants were put in the kiln for 24 hours.

For cutting the whole plants into choppers a single-row drum corn harvester SIP SK-80 (Fig. 3) was applied. A chop unit with 16-knife-drum and the crushing plate served for a short and exact cut of plant and the crushed grains. Cut length was regulated on 4 mm length and a driving speed was set on 3.17 km h^{-1}, which ensured a working capacity of 40-45 tons of silage corn per one hour [8].

Fig. 3. Harvesting silage corn with a single-row drum corn harvester SIP SK-80

The measured data were analyzed using the statistical package SPSS 14.0 for analysis of variance. Duncan's Multiple Range Test at P< 0.05 was used to compare the means of the obtained results in the experiment.

3. Description of achieved results

3.1. Emerged seedlings

The main statistics, which describes the effect of different seeding methods on the seed emergence in Noršinci is represented in the Table 4 and in Pohorski dvor in the Table 5. As seen the highest percentage of emergence was detected in both location on parcels with conventional treatment (V5); in Noršinci (98.99 %) and 82.75 % in Pohorski dvor.

Table 4.
The effect of different seeding system on the emergence of corn in percentage (Noršinci, 2007)

Treatment	Emergence $\bar{x}$	SD	CV
V5	98.99 [a]	4.33	4.37
V3	97.13 [a]	4.21	4.33
V4	95.28 [a]	5.14	5.39
V2	84.22 [b]	5.32	6.31
V6	82.56 [b]	4.77	5.78
V1	82.48 [b]	5.63	6.82

[a, b] significant at $p<0.05$ Duncan test

Table 5.
The effect of different seeding system on the emergence of corn in percentage (Pohorski dvor, 2007)

Treatment	Emergence $\bar{x}$	SD	CV
V5	82.75 [a]	1.71	2.06
V3	75.74 [a]	5.40	7.13
V4	73.50 [a]	6.88	9.36
V2	71.75 [b]	4.34	6.05
V6	65.25 [b]	7.98	12.22
V1	63.25 [b]	6.53	10.32

[a, b] significant at $p<0.05$ Duncan test

As seen, in Pohorski dvor the gliphosat treatment one week before seeding (V1) influenced the lowest emergence with 63.25%, followed focus ultra treatment on the whole parcel three weeks after seeding 65.25%. In Noršinci the same treatment affected the lowest emergence as well, however it was much higher 82.48% (V1) and 82.56% (V6). The main reason for higher emergence in Noršinci lies in the difference between soil types, and soil preparation for the previous crops in rotation. Although, the lowest emergence was also detected in the treatment (V1), where the gliphosat was applied one week before seeding of silage corn, it was still for one fifth higher. However, it did not differ from the emergence, when the focus ultra was applied 3 weeks after seeding (V6) nor in the case of the treatment V2, when the focus ultra was applied 3 weeks after the mowing of perennial rye grass before seeding.

The main reason for lower emergence with V6, V3 and V2 treatment lies in the focus ultra herbicide, which obviously worked inefficient on ryegrass and therefore started to grow again and subsequently effect very competitively on the emerged corn seeds. Similar effect of the conventional tillage in comparison with the direct seeding was also reported by Košutić et al, Tajnšek and Zimmer et al [9, 16, 18].

3.2. Moisture content

The different moisture content of whole plants in on both locations is presented in Table 6 and Table 7.

Table 6.
The effect of different seeding system on the moisture content of whole plants in percentage (Noršinci, 2007)

Treatment	Moisture $\bar{x}$	SD	CV
V4	45.1 [a]	2.71	6.00
V5	44.3 [a]	2.40	5.41
V6	43.6 [a]	1.88	4.31
V1	42.8 [a]	2.34	5.47
V3	41.7 [b]	1.98	4.75
V2	40.4 [b]	2.53	6.26

[a, b] significant at $p<0.05$ Duncan test

On both locations the highest moisture was measured in the treatment V4; 45.1 % in Noršinci and 47.6 in Pohorski dvor. Significantly lower moisture was detected on parcels V2 and V3

(Noršinci) and as well as on V2 in Pohorski dvor. It is very difficult to explain the main reason for differences in the moisture content; however it is probably the died-away layer of perennial rye grass, which speeds up the drying of the plants on those particular plots.

Table 7.
The effect of different seeding system on moisture content of whole plants in percentage (Pohorski dvor, 2007)

Treatment	Moisture $\bar{x}$	SD	CV
V4	47.6 [a]	2.95	6.20
V3	47.1 [a]	3.09	6.56
V1	47.0 [a]	2.50	5.32
V6	46.7 [a]	2.80	5.99
V5	45.7 [a]	2.76	6.03
V2	41.9 [b]	2.98	7.11

[a, b] significant at p<0.05 Duncan test

3.3. Corn silage yield

The highest yields of fresh corn silage were produced in Noršinci (50.590 kgha^{-1}) as well as in Pohorski dvor (45.661 kgha^{-1}) with the conventional tillage system (Fig. 4, Fig. 5). In Noršinci the significant lower yield was measured only with V6, V3 and V2 seeding method, while there was no difference to V1 and V4 system. The same tendency can be seen in Pohorski dvor as well, whereby the alternative soil tillage V1 resulted practically the same yield as V5 with less energy and time input. However, on the average the yield in Pohorski dvor was lower for 3.216 kg ha^{-}1, due to the silty clay loam soil, which was rather dry in the time of sowing. The main reason for higher yields in Noršinci lies in the difference between soil types, soil preparation for the previous crops in rotation and the moisture content of the soil at the tillage.

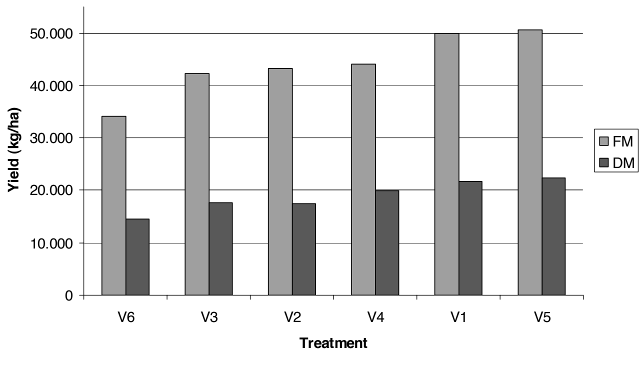

Fig. 4. The fresh and dry matter yield of silage corn affected by different seeding (Noršinci, 2007)

The maximum yield on parcels V5 corresponds very close to the highest percentage of seedlings, which was already reported by Linden. However, the most important conclusion can be conducted whenever looking on parcels with the treatment V1, on which practically the same fresh matter than on V5 was produced, although there was a significant lower emergence on Noršinci 82.48 % as well as Pohorski dvor 63.25%. The corn plants evidently compensated the lower emergence, due to the better air and water condition, which was created with the died-away layer after the gliphosat treatment on perennial rye grass. The same effect was detected on the V4 parcels, on which the inter-row space was cut with the hand mower 3 weeks after seeding.

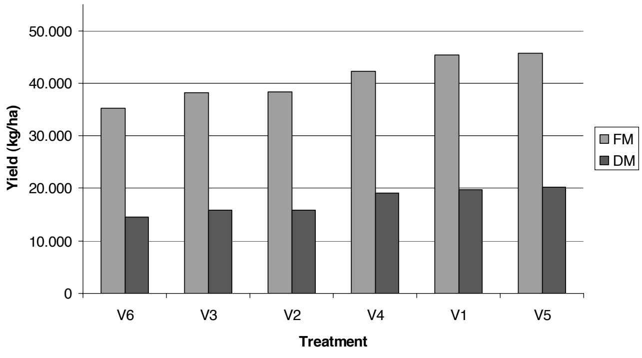

Fig. 5. The fresh and dry matter yield of silage corn effected by different seeding (Pohorski dvori, 2007)

The results of our investigation are very close to some earlier experiments with a two- and four-year rotation [16], in which the higher yield of corn was also produced with the conventional tillage than with reduced tillage system. However, a newer alternative direct seeding system showed important advantages, because it is faster, cheaper and produced less CO_2 emissions.

3.4. Soil resistance

The average results of the penetrometer probes taken on September 29th are represented in Fig. 6 and Fig. 7.

In Noršinci on the first 5 cm layer the lowest soil resistance (30.88 N cm^{-2}) was measured under conventional tillage (V5), and the highest (55.73 N cm^{-2}) on parcels treated with focus ultra in bands 3 weeks after seeding (V3). Those findings lies very close to the Bayhan et al [1].

However, on 15 cm layer on parcels with the gliphosat treatment 1 week before seeding (V1) the lowest (35.49 N cm^{-2}) resistance was detected. On the other hand the V3 treatment showed the highest soil resistance (84.73 N cm^{-2}).

On the 25 cm layer practically all values lies round 72 N cm^{-2} except V3, which was again the outstanding with (102.20 N cm^{-2}).

At the 35 cm layer all treatments reached almost the same values at round 93.00 N cm^{-2}, which corresponds quiet well to the ploughing shift caused by constant ploughing at the same depth in the previous years.

At the last clacking point at 45 cm layer all values exceeded previous values, whereby plots with V4 treatment exceeded most with 185.31 N cm^{-2}, due to the unploughed subsoil layer.

On Pohorski dvor in the average higher values of soil resistance was measured in the average. Whenever looking in the details in the first 5 cm layer the lowest soil resistance (57.22 N cm^{-2}) was measured under conventional tillage (V5), and the highest (83.85 N cm^{-2}) on parcels treated with focus ultra in bands 3 weeks after seeding (V3). Those findings lie very close to Bayhan et al and [1,18].

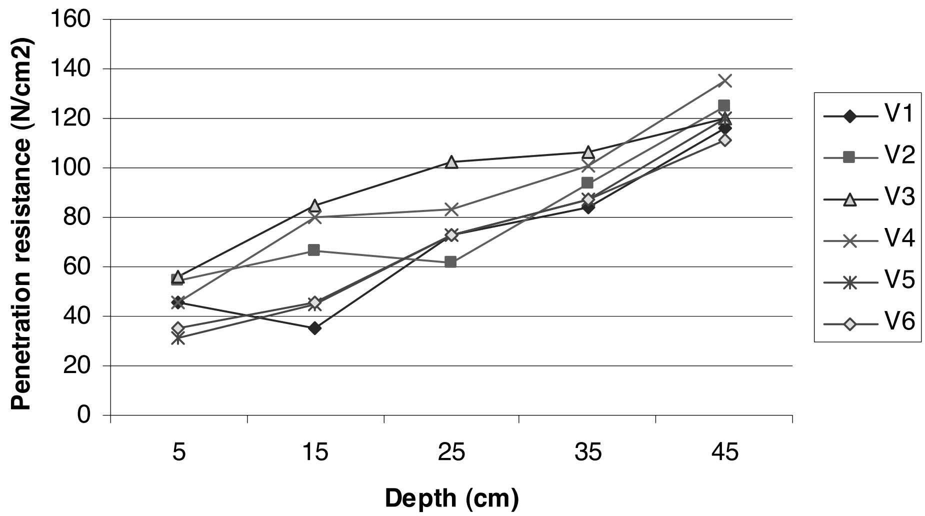

Fig. 6. The effect of different seeding on the penetrometer resistance (Noršinci, 2007)

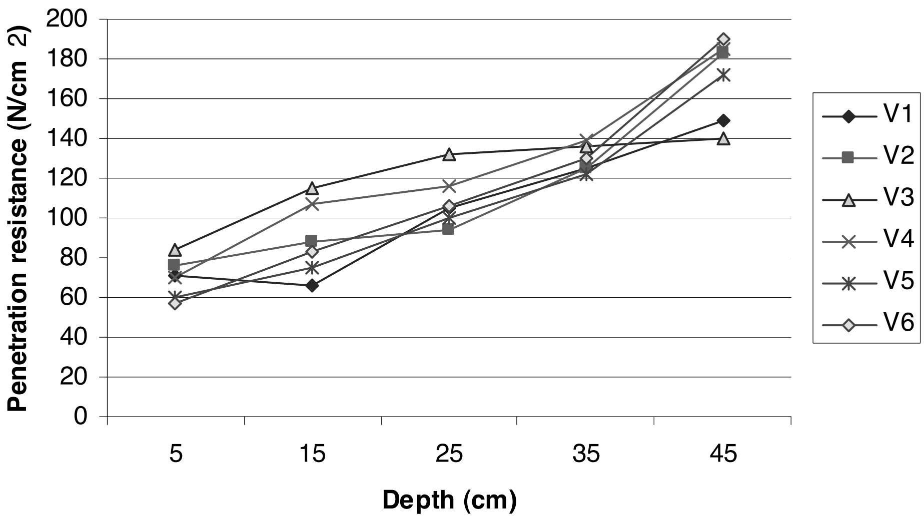

Fig. 7. The effect of different seeding on the penetrometer resistance (Pohorski dvor, 2007)

However, on 15 cm layer on parcels with the gliphosat treatment 1 week before seeding (V1) the lowest (65.56 N cm^{-2}) resistance was detected. On the other hand the V3 treatment still showed the highest soil resistance (115.44 N cm^{-2}).

On the 25 cm layer practically all values lies round 108.00 N cm^{-2} except V3, which was again the outstanding with (131.71 N cm^{-2}).

At the 35 cm layer all treatments reached almost the same values at round 129.00 N cm^{-2}, while corresponds quiet well to the ploughing shift caused by constant ploughing at the same depth in the previous years. At the last clacking point at 45 cm layer all values exceeded previous values, whereby plots with V6 treatment exceeded most with 189.89 N cm^{-2}, due to the undisturbed subsoil layer.

In upper 0-25 cm layer cone resistance was the lowest in the conventional tillage (V6) and the highest (131.71 N cm^{-2} in focus ultra in bands 3 weeks after seeding (V3). The second densest samples (115.94 N cm^{2}) were measured on parcels V4 (treatment with focus ultra three weeks in bands, mowing inter-row bands).

4. Conclusions

High fuel consumption and short time of optimal soil conditions for basic soil tillage forced researchers all over the world to look for new tillage and seeding systems. The experiments were conducted on two most important arable land production locations in Eastern Slovenia, which involved conventional tillage with mould board plough and rotary harrow (V5) as standard procedure and five different direct seeding methods. The silage corn was seeded into four-year rotation after the perennial rye grass, which was treated with gliphosat treatment 1 week before seeding (V1), mowing + focus ultra on the whole plot 3 weeks later (V2), mowing + focus ultra in bands 3 weeks later (V3), mowing + focus ultra in bands 3 weeks later + mowing the inter row space after emergence (V4), focus ultra on the whole plot 3 weeks after seeding (V6).

The highest percentage of emergence was detected on both location on parcels with conventional treatment (V5); in Noršinci (98.99%) and 82.75% in Pohorski dvor.

The results of field experiments showed that the highest yield of silage corn was produced on both locations under the conventional tillage 50.590 $kgha^{-1}$ (Noršinci) and 45.661 $kgha^{-1}$ (Pohorski dvor). However, in case of V1 (Pohorski dvor) and V1 and V4 (Noršinci) the young growing corn plants managed to compensate the lower number of emerged seedlings, so there was no statistical difference on those particular parcels.

The measurements with the penetrometer showed significant differences in the soil resistance on both locations due to the different soil type, textures and previous tillage system. However, the most important findings are connected with the influence of the new seeding methods on the soil resistance within particular locations. From these reason on the 5 cm layer the lowest soil resistance was measured on both locations under conventional tillage (V5), while in Noršinci on other layers the highest value (119.78 N cm^{-2}) was detected on parcels treated with focus ultra in bands 3 weeks after seeding (V3). Contrary, on Pohorski dvor the maximum soil resistance (185.31 N cm^{-2}) were measured parcels treated with focus ultra in bands 3 weeks after seeding and additional mowing the inter row space after emergence (V4).

The benefits of non-conventional tillage systems application could significantly contribute not only to the yield of fresh matter silage corn, but also improve environmental protection due to decrease of CO_2 emission and soil water conservation, and not last the economic result of farmers.

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