Impact of sowing speed on the introduction of winter wheat seeds in differently-tilled soils

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Abstract. Research tests in Europe disclosed that minimized soil tillage changes the soil qualities, the distribution of harvested crop residues (especially straw) in the soil, and the conditions of seed introduction into the soil, etc. In addition, completely different requirements are needed for design and technological parameters of the seeders in minimal soil tillage or no-tillage soils if compared with traditional seeders used in tilled soils.

The paper describes the tests of winter wheat sowing in differently-tilled soils. The impact of the sowing speed of the winter wheat seeds on the even introduction and the distribution of the various size soil lumps in the seed bed layers was investigated. Furthermore, the change of the soil hardness and moisture content in various soil depths in differently-tilled soils was tested.

Research suggested that the soil hardness in the winter wheat seed introduction zone in minimal soil tillage or no-tillage soils was approximately 250 kPa, and was significantly lower in tilled soil, i.e., 100 kPa. When winter wheat seeds were sown into no-tillage soil the sowing speed had greater impact on the composition of the soil lumps in the seed bed if compared with other more intensive soil tillage technologies. The tests disclosed that when the speed of the drill was increased from 8 to 12 km h^{-1}, the number of small soil lumps (<2 mm) in all the layers of seed bed minimized and the amount of larger than 5 mm soil lumps maximized. The even introduction of seeds was negligible in minimal tillage soils.

Key words: sowing speed, winter wheat, soil tillage, seed bed, soil lump fraction

INTRODUCTION

No-tillage soil technologies are rapidly spreading in Lithuania. Researchers have proved that sowing into minimal soil tillage or no-tillage soils improves the soil structure, increases biological soil activity, reduces soil erosion, compacts soil surface less, and saves labour and power expenditures (Haberland, 1997; Tebrügge et al., 2000; Germanas, 2000, Šarauskis, 2001; Fallahi et al., 2008). The direct no-tillage sowing method is used in large soil areas in Europe. During the past few years approximately 960,000 ha of arable lands or 1.8% of the whole area was planted using direct no-tillage technique (Linke, 2006).

Cereals are sown with drills either with mechanical or pneumatic seed metering apparatus. The type of apparatus has no significant impact on the quality of seed introduction into the soil. Ploughshares of different designs can be used for seed introduction into cultivated soils but disc ploughshares are recommended in minimal soil tillage or no-tillage soils. They penetrate into hard soil surfaces more effectively and are less contaminated with the previous harvest crop residue (Šarauskis et al., 2005).

The drill speed is very important in sowing. The due sowing speed provides the quality of seed introduction and high labour efficiency (Ozmerzi et al., 2002; Ivancan et al., 2004). When conventional drills are used in tilled soils, the most suitable sowing speed is about 10 km h^{-1} (Soucek et al., 1990). Insufficient research has been done to test the sowing speed in minimal soil tillage or no-tillage soils. Western European researchers suggest that the minimum sowing speed should be from 8 to 12 km h^{-1} when the drills with disc ploughshares are used in minimal soil tillage or no-tillage soils (Köller et al., 1997; Linke, 1998).

The sowing speed tests in minimal soil tillage or no-tillage soils in Lithuania were conducted only with sugar beet. The change of the seed bed parameters was tested when the sowing speed varied from 5 to 9 km h^{-1} (Šarauskis, 2001).

It is crucial that seed bed preparation for sowing is done properly. Crop germination, development, yield and quality depend on the conditions in the seed bed. Soil structure is also very important for the crop growth (Rademacher, 1988; Steinert, 1994). The soil structure is divided according to lump size: mega structure – when the soil lumps are from 10 to 50 mm, macro structure – when the soil lumps are from 10 to 0.25 mm, and micro structure – when the soil lumps are less than 0.25 mm in size (Romaneckas et al., 2003). The most benevolent soil structure for plant growth is when soil lumps of 2-5 mm in size prevail. When the soil has more than 5-7% of micro lumps, it becomes dry more quickly, and the soil crust forms more readily after the rain. When the soil has more than 30% of lumps from 10 to 50 mm in size, the contact of seeds with the soil becomes worse thus they cannot be introduced into the proper depth and their germination is uneven or delayed (Naudžiūnas, 1996; Romaneckas et al., 2003).

The goal of this research is to investigate the impact of the winter wheat sowing speed on the even seed introduction, the distribution of the composition of the soil lumps in the seed bed, as well as to determine the change of the mentioned parameters in differently-tilled soils.

MATERIALS AND METHODS

In 2005–2006 the tests of winter wheat sowing were fulfilled in the farm of A. Miežis in Pakruojis region. Three different variants of the tests were conducted in clay loam soil:

1 – Conventional soil tillage (ploughed soil cultivated with S-tine cultivator and pressed with the roller)

2 – Minimal soil tillage (non-ploughed soil cultivated with rotary tiller)

3 – No-tillage (non-tilled stubble)

Winter wheat "Ada" (sowing rate 250 kg ha^{-1}, seed introduction depth 30 mm) was sown by the disc drill "Rabe Mega Seed" at the field speed of 8, 10 and 12 km h^{-1}.

The tests of soil moisture content, hardness and lump number were made previous to sowing in all the plots cultivated by various tillage techniques. The soil hardness was measured with a penetrologger. Before the test the conical tip of the device was mounted on the end of the probe rod. Four different tips can be used depending on the soil resistance. The probe rod is connected to the shock absorber under the penetrologger. When the conical tip was pressed into the soil the inner ultra-sound sensor of the penetrologger accurately registered the depth up to 800 mm with the help of the referential plate. When the soil hardness was tested three measurements were taken in the area of 1.0 m^2. The soil hardness and resistance to penetration data, and measurement coordinates (GPS data) were registered and stored in the drive of penetrologger. The measurement data was stored in the computer by connecting it to the penetrologger.

The sieve set was used to determine the number of soil lumps after the soil tillage before sowing. It consisted of a rectangular metal frame (0.5x0.5 m) with the walls of 0.1 m height. The metal sieves with oval perforations of various diameters were rigidly joined to the frame.

The soil was divided into 4 different lump fractions:

- lumps greater than 50 mm;
- lumps from 25 to 50 mm;
- lumps from 10 to 25 mm;
- lumps smaller than 10 mm.

The investigation of the seed bed indices specified the change of the composition of soil lumps, soil moisture content in various layers, seed introduction depth at various field speeds of the drill. The seed bed indices were defined using Kritz/Hakansson method (Hakansson et al., 2002; Romaneckas et al., 2003).

To fulfill the seed bed test the frame (400x400 mm, 100 m height) with the tip-up small frame at one side (250x400 mm, 100 mm height) was used. The frame was pressed into the soil and its horizontal position was checked with spirit-level. The small frame was pressed into soil above the sowing row and three soil layers were dug out with the spade at increments of 15 mm from this area.

The excavated soil layer was separated through the upper 5 mm sieve and lower 2 mm sieve. After soil separation three soil lump fractions were as follows: >5 mm, 2-5 mm, and < 2 mm size soil lumps. The per cent composition of the lump fractions of individual layers was determined by pouring different fractions into a 2-litre measuring bulb.

The seeds separated from every individual layer were calculated and the even seed distribution in the seed bed was estimated. Tests were done in 3–5 replications in various soil locations.

Three samples were taken from each soil layer to determine the soil moisture content in the seed bed. These samples were placed in the separate boxes. Soil moisture content in three various layers of seed bed (0–15 mm, 15–30 mm, and 30–45 mm) were calculated by weighing and drying.

The drill speed was recorded in the tractor dashboard speedometer.

Data obtained by investigation was evaluated using methods of dispersion and correlation-regression analysis. Arithmetic means, their standard errors, and confidence intervals at probability level of 0.95 were determined.

RESULTS AND DISCUSSION

Soil moisture content has great impact on seed germination ability and further growth of the crops. The soil moisture content has been determined in the upper soil surface at the depth of 45 mm. Soil moisture content before the winter wheat sowing in all the soil tillage variants was too small (< 10%). It was specified that the soil moisture content in various depths of minimal soil tillage or no-tillage soils did not change significantly but the upper surface of the tilled soil had smaller moisture content if compared with the moisture content in deeper soil layers (Fig.1).

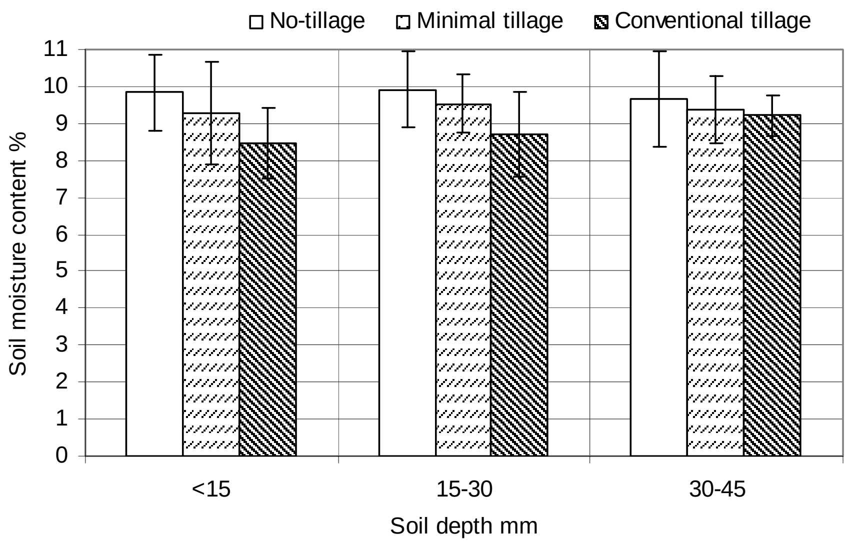


Fig. 1. Soil moisture content dependence on the soil tillage technologies.

The optimal soil moisture content in the seed bed in clay loam soils for winter wheat sowing is 16-18 percent. During the sowing test the weather was rather dry thus winter wheat was sown into rather dry soil.

After the soil hardness tests before the sowing of winter wheat had been fulfilled the conclusion was made that the soil hardness in the seed introduction zone (30 mm depth) in minimal soil tillage or no-tillage soils was about 250 kPa, and in the tilled soil it was significantly smaller – about 100 kPa (Fig.2).

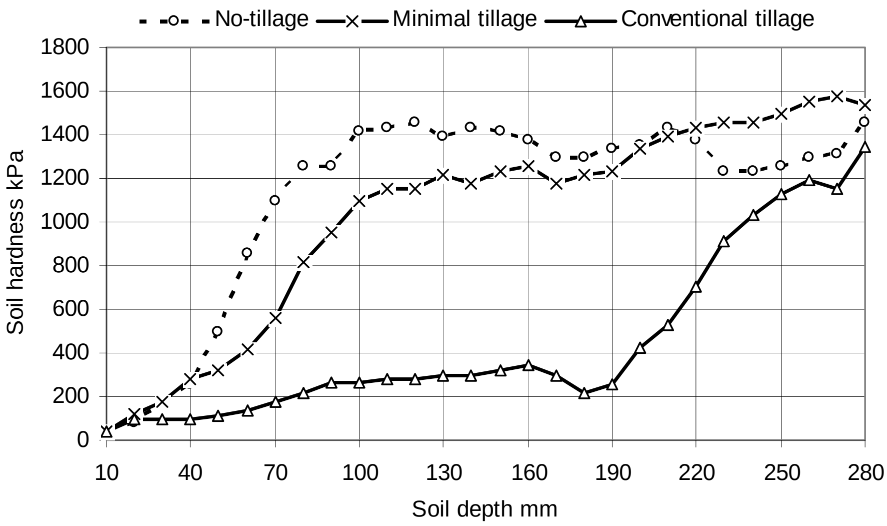


Fig. 2. Impact of various soil tillage technologies on the soil hardness.

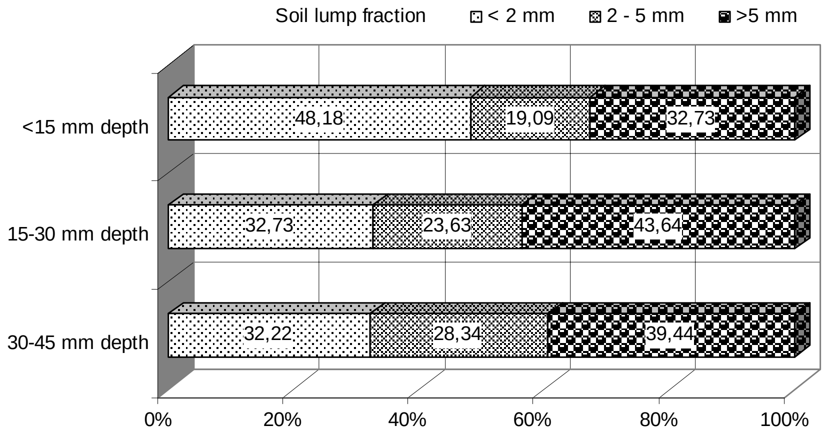
Soil hardness in tilled soil in the depth up to 200 mm was approximately 3–4 times less than in minimal soil tillage or no-tillage soils. Seeds were introduced into the porous soil surface in the tilled soil. Soil hardness has great impact on the operation of the ploughshares of the drill, especially for even seed introduction. Plant remains may sometimes occur on the surface or in shallow layers of of non-tillage soils. When the soil is very porous the disc share or disc knives cannot cut these plant remains and are pressed into the bottom of the seed bed.

When the soil was tilled using various techniques before the sowing of winter wheat the lump number in the soil has been also determined. There was no significant variance between the lump sizes in the differently-tilled soil. Soil lumps that were smaller than 10 mm comprised about 60% in all test replications. Larger than 50 mm soil lumps in minimal soil tillage or tilled soils comprised about 6–7%, and in no-tillage soils a bit more (about 10%).

Impact of sowing speeds on seed introduction. The seed bed was tested in the soils where various tillage technologies were used to sow winter wheat using different speeds (8, 10 and 12 km h^{-1}). Even seed introduction, composition of soil lumps and soil moisture content above the seeds (at the depth of 0–15 mm), beside the seeds (15–30 mm), and under the seeds (30–45 mm) were the parameters investigated.

When the soil lump composition in the seed bed in traditionally tilled soils was tested the conclusion was as follows: when winter wheat had been sown at the speed of 8 km h^{-1}, the soil lump distribution beside the seeds and under the seeds was normal (Fig. 3). Too many small (< 2 mm) soil lumps were found in the upper soil layer (48.18%).

When the sowing speed in the tilled soil was increased the number of small soil lumps decreased and the number of lumps greater than 5 mm increased in the seed bed under the seeds (at the depth of 15–45 mm).



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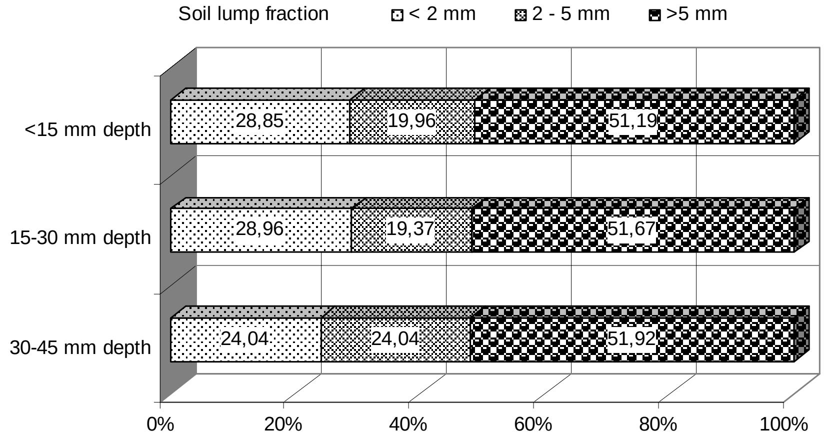

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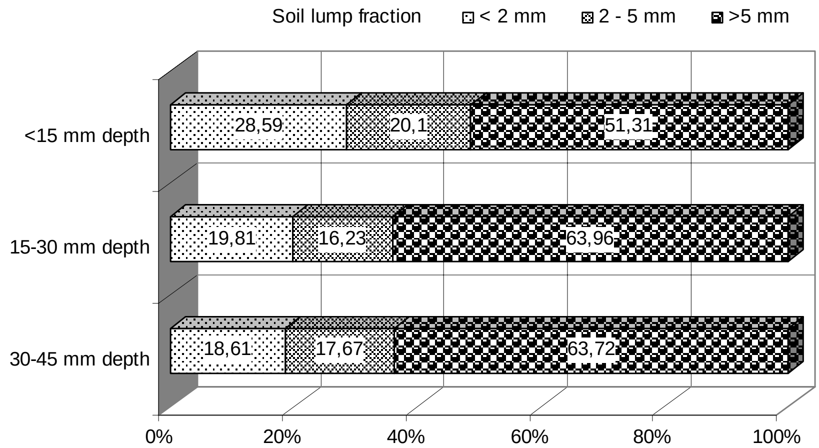

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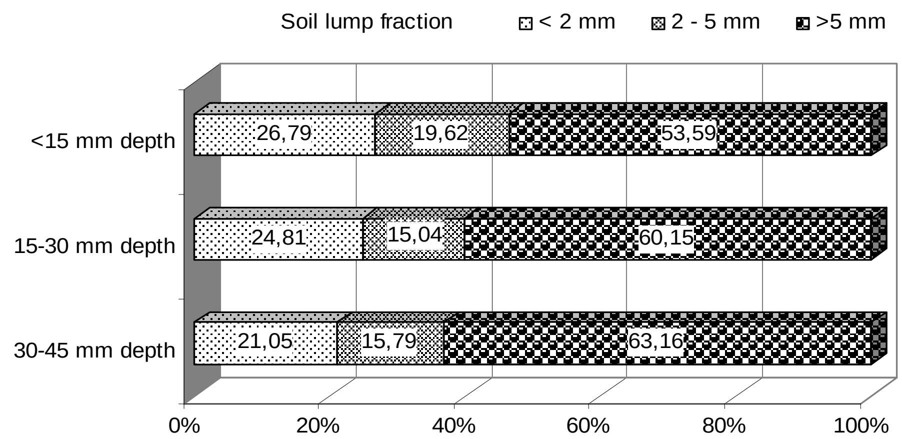
Fig. 3. Lump composition in the seed bed of tilled (ploughed) soils when winter wheat was sown using different speeds: a) 8 km h^{-1}, b) 10 km h^{-1}, c) 12 km h^{-1}.



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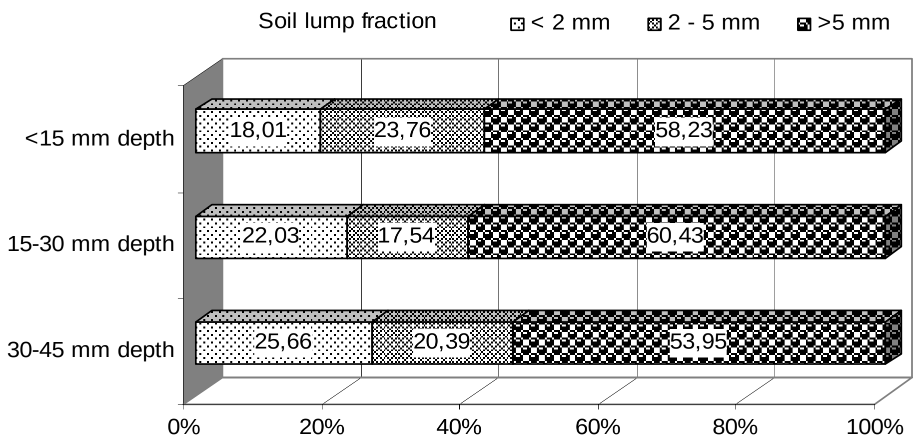

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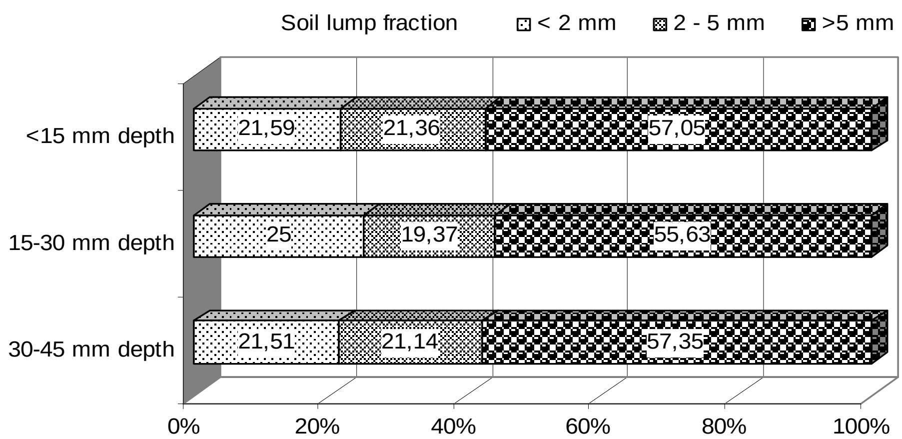

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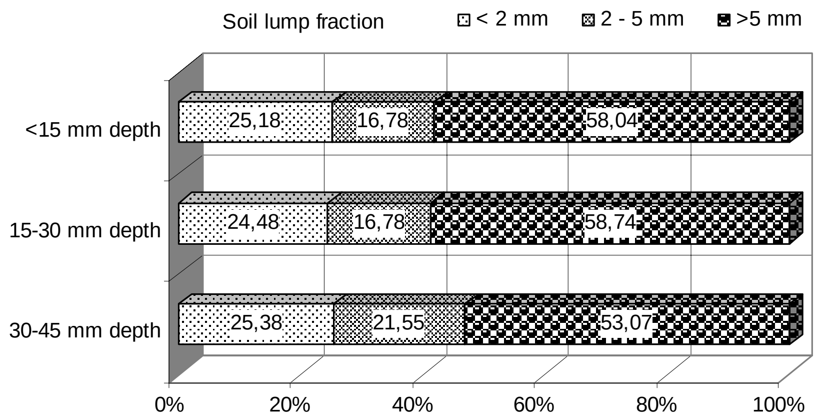
Fig. 4. Lump composition in the seed bed of minimal tillage soils when winter wheat was sown at various speeds: a) 8 km h^{-1}, b) 10 km h^{-1}, c) 12 km h^{-1}.



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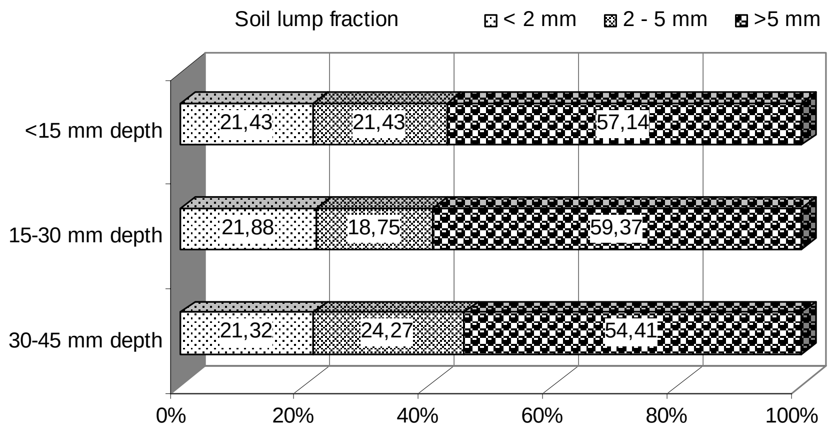

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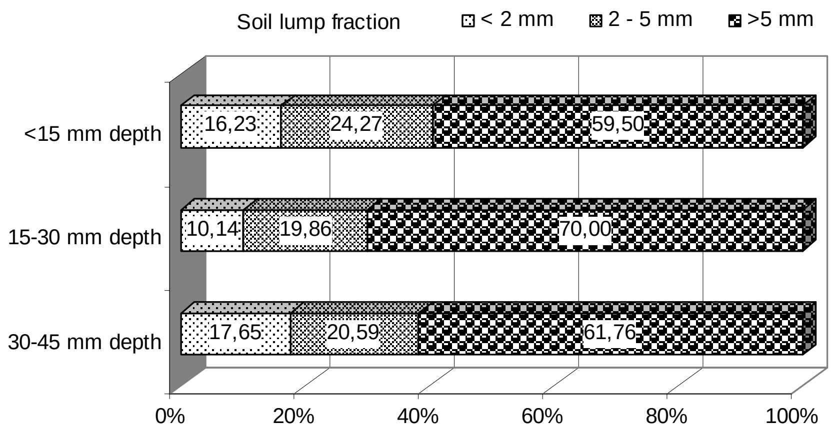

c)

Fig. 5. Lump composition in the seed bed of no-tillage soils when winter wheat was sown at various speeds: a) 8 km h^{-1}, b) 10 km h^{-1}, c) 12 km h^{-1}.

When winter wheat was sown into minimal tillage soils the lump composition of the soil in seed beds was similar in all three sowing speed variants. Small (<2 mm) soil lumps comprised about 18–26%, big (> 5 mm) soil lumps comprised about 53–63%, the part of the soil lumps was 2–5 mm in size (Fig. 4). When the sowing speed was changed the composition of soil lumps in the seed bed changed insignificantly, i.e., within the limit of error.

When winter wheat seeds were sown into no-tillage soils, the sowing speed had greater impact on lump composition in the seed bed than in other tests where more intensive soil tillage technologies were used. It was concluded that when the field speed of the drill was increased from 8 to 12 km h^{-1}, the amount of small (< 2 mm) soil lumps in all the layers of the seed bed decreased, and the amount of larger than 5 mm soil lumps increased (Fig. 5). This is especially obvious when the seed speed was increased to 12 km h^{-1}.

The reasons why the composition of soil lump changes in various layers of the seed bed when the sowing speed was changed are not clearly seen. The greatest impact on this process might have been on physical and mechanical characteristics of the soil, the design of ploughshares, and the distribution and design of the seed rollers that press the seeds. The interaction of the operating parts of the drill with the soil, the duration of such interaction, etc. are also very important factors.

Even introduction of seeds. The sowing speed of the winter wheat in differently tilled soils had considerably greater impact on the even seed introduction than on the lump composition in the seed bed.

Tests showed that when winter wheat was sown in the soil tilled at the speed of 8 km h^{-1}, all seeds were introduced deeper than 45 mm (Fig. 6). When the sowing speed was increased, the soil resistance force against the drill ploughshares introduction into the soil increased, therefore, the ploughshares were raised closer to the soil surface. When the sowing speed was 10 km h^{-1}, 7% of winter wheat seeds were introduced into the depth of 40 mm, and when the sowing speed was 12 km h^{-1}, about 11% of seeds were introduced in the above mentioned depth.

The impact of sowing speed on the even seed introduction became more obvious after the tests in minimally tilled soils. All the seeds were introduced at the depth of 30 mm and deeper in the soil where the drill speed was 8 km h^{-1}, 54% of the seeds were at the depth from 30 to 45 mm, the remaining seeds were deeper than 45 mm (Fig. 7). When the sowing speed was increased up to 10–12 km h^{-1}, the drill ploughshares operated closer to the soil surface, therefore, fewer seeds were introduced deeper than 45 mm and more seeds were closer to the soil surface (at the depth of 0–15 mm and 15–30 mm).

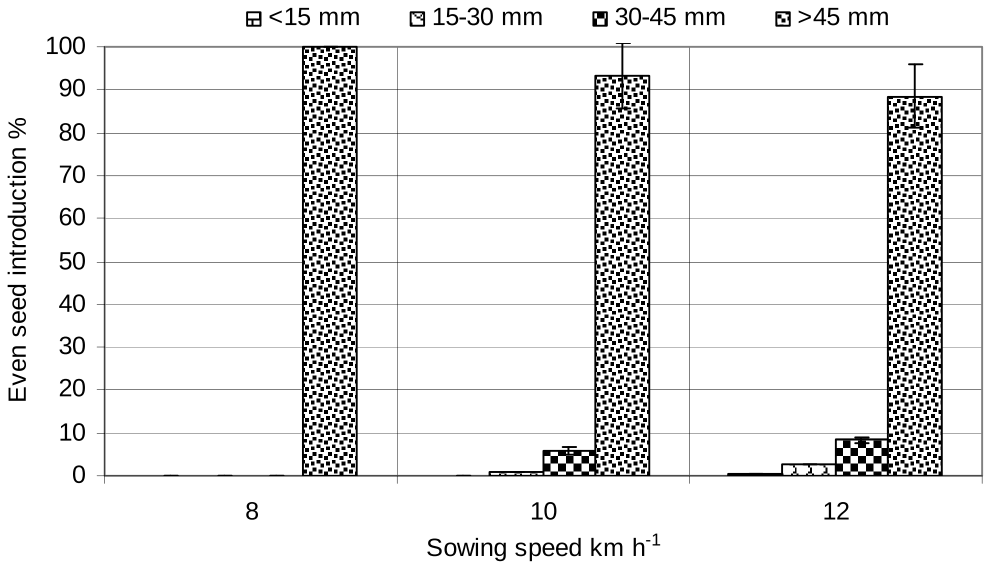

Fig. 6. Impact of sowing speed on the even winter wheat seed introduction into the tilled (ploughed) soil.

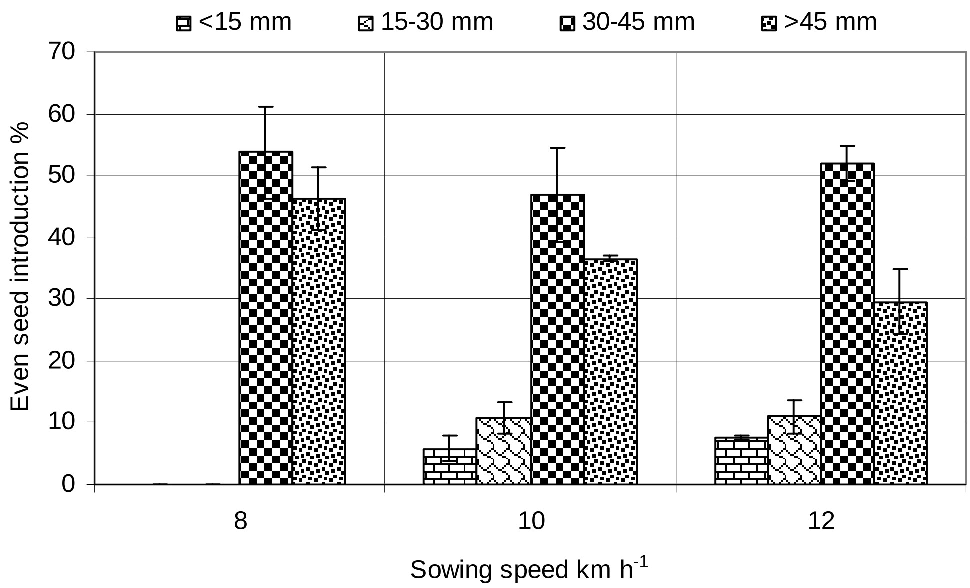

Fig. 7. Impact of sowing speed on the even winter wheat seed introduction into minimal tillage soil.

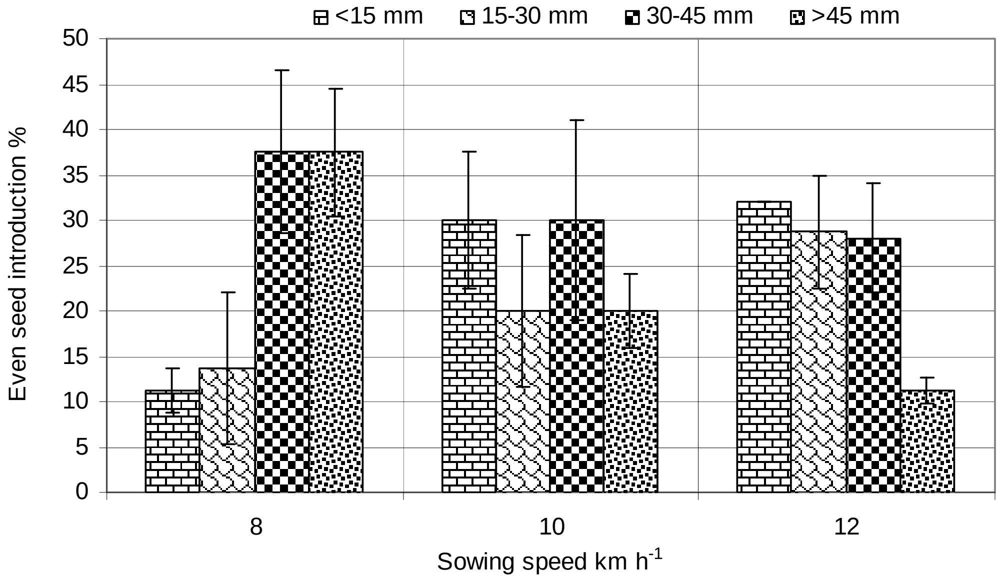

Fig. 8. Impact of sowing speed on the even winter wheat seed introduction into no-tillage soil.

Tests in no-tillage soils (stubble) showed that when the sowing speed was 8 km h^{-1}, approximately 25% of winter wheat seeds were introduced into the upper layers of the soil (less than 30 mm depth), about 38% were introduced deeper than 45 mm, the remainder at the depth of 30–45 mm (Fig. 8).

When the sowing speed was increased from 8 to 12 km h^{-1}, the amount of seeds in the upper layers of the soil (up to 30 mm) maximized from 25 to 61%, and the number of seeds that were introduced deeper than 45 mm minimized to 12%.

Tests of the winter wheat sowing into the no-tillage clay loam soils showed that seeds are more evenly distributed at lower speeds. When the sowing speed is increased the seeds are introduced into various depths, and this can seriously affect the even seed germination. When the sowing speed was (12 km h^{-1}), the drill ploughshares worked in more shallow soil layers, and they were completely raised to the soil surface when blocked with plant residues from the previous yield. Then in spring, the ploughshare returned them into the previous depth. At this moment the ploughshares were additionally acted upon by inertial forces, and as a result, a significant portion of the seeds were often introduced too deeply, at more than 45 mm.

The soil hardness in no-tillage soils (stubble) was greater than in tilled or minimal-tillage soils, thus the drill ploughshares had to be pressed by greater force to be introduced into such soils.

CONCLUSIONS

The reduction of soil tillage intensity enables preserving greater moisture content in the soil surface. This is especially obvious when the rainfall is not sufficient during sowing and seed germination. The reduction of soil tillage intensity enables increasing the hardness of the upper soil layer: the soil hardness of tilled (ploughed) soils was 2–4 times less than that of no-tillage soils.

When winter wheat sowing speed was increased, the even introduction of seeds was decreased due to the change of the drill ploughshare resistance to the soil. At greater speeds and especially when the obstacle (e.g., lump, stone, etc.) was encountered, the ploughshares rise to the soil surface more readily and the seeds are spread on the soil surface or introduced into various soil layers.

Even seed introduction was also reduced when the intensity of soil tillage was minimized. When the soil was ploughed and cultivated, all plant residues of the previous yield are introduced into the deeper soil layers and did not obstruct seed introduction. When the soil tillage intensity was minimized, the soil surface became harder, the greater part of the plant residues remained in the soil surface or was introduced into the upper soil layers, preventing seed introduction.

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