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Impact of seedbed density on sugar beet (*Beta vulgaris* L.) seed germination, yield and quality of roots

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Abstract

The aim of pot experiments was to determine optimal values of sugar beet seedbed density in laboratory conditions and its influence on seed field germination, yield and quality of roots in field conditions. In a pot experiment sugar beet seeds were sown into the soil with different bulk densities of upper seedbed layer-from 0.8 to 1.4 Mg m^{-3}. In a field trial sugar beet seedbeds were compacted by Cambridge (CRB) and spur (SRB) rollers before and after (CRA and SRA) sowing. Plots of control treatment were not rolled (NR). According to the results of the pot experiment, the most rapid sugar beet seed germination was in the seedbeds of 1.0 Mg m^{-3} soil bulk density. The optimal soil bulk density for final sugar beet seed germination was from 1.0 to 1.1 Mg m^{-3}. Seed germination was 46 and 54% higher than in the soil of 0.8-0.9 Mg m^{-3} density. After sowing soil rolling affected lower seedbed compaction level and higher moisture losses. Soil rolling by Cambridge roller after sowing (CRA) positively affected on sugar beet root yield and quality.

Key words: Sugar beet, seedbed density, germination, yield, quality.

Introduction

Sugar beet (*Beta vulgaris* L.) is very sensitive to physical conditions in the seedbed [1], because sugar beet seedlings have a low emergence force, about 0.15 N [15]. Sugar beet germinates very slowly or not at all if the conditions of seedbed (oxygen or water content, temperature, mechanical composition, high soil bulk density) are not optimal [2, 4, 8]. According to the investigations, seeds should be incorporated into the denser seedbed layer and covered by crumbly soil [3, 5]. Established soil bulk density of sugar beet seedbed down is 1.1-1.3 Mg m^{-3}, upper seedbed layer 0.8-0.9 Mg m^{-3} [18]. According to German scientists, optimal soil bulk density of arable layer for sugar beet is 1.27-1.37 Mg m^{-3}. The increase of bulk density from optimal means by 0.01 Mg m^{-3} decreases yield of roots by 0.4 t ha^{-1} [16, 17].

Soil rolling improves its aggregate consolidations, increases capillary moisture movement to seed zone and influences better seed germination [12]. In light and heavy soils rolling reduced and in intermediate textured soils increased evaporative water losses[6]. On the other hand, rolling can reduce seed germination and yield of crop due to increase of soil compaction or crust formation.

Sugar beet seedbed density over laboratory and field conditions has not been much investigated in Lithuania. The aim of the investigations was to determine the optimal means of sugar beet seedbed upper layer density in laboratory conditions and in field experiment to establish the influence of soil compacting implements (rolls) on seed field germination, yield and quality of roots.

Materials and Methods

Pot experiment: A pot experiment was carried out in the laboratory of the Department of Soil Management in March 2008. Silty loam Luvisol was used. The soil was neutral and the amount of phosphorus was equal to 240-280 mg kg^{-1}, that of potassium 115-129 mg $kg^{-1}$and organic carbon content 1.9-2.1%. There were five replications of randomized design. We used 200 cm^3 and 8 cm height metal cylinders for each treatment. The soil bulk density of seedbed down (5 cm layer) was 1.4 Mg m^{-3}, upper layer (3 cm height) from 0.8 to 1.4 Mg m^{-3}. Soil bulk density of 0.8 Mg m^{-3} was control treatment. Sowing depth was 3 cm, according to the usual sowing practice in Lithuania [11, 14]. Sugar beet "Klarina" (KWS, Germany) variety was used. Fertilizers were not applied. Initial conditions of trial were as follows: soil gravimetric moisture content 20.0 g kg^{-1}; germination air temperature 12-14°C (optimal temperature for seed germination period in field conditions in Lithuania [10]) and additional illumination rate 7-8 hours per night (to avoid seedling extension). The data were analysed by ANOVA and regression analysis by SigmaPlot 8.0 software.

Field experiment: The investigations were carried out on the same soil as the pot experiment at the Experimental Station of Lithuanian University of Agriculture in 2007. The field experiment was arranged according to the following scheme: sugar beet seedbeds were compacted by Cambridge (CRB) and spur (SRB) rollers before and after (CRA and SRA) sowing. Plots of control treatment (NR) were not compacted. The working width of

Cambridge roller (make of implement KKN-2.8) is 2.8 m, mass for one metre of working width 256.4 kg. Spur roller's (make of implement 3KKŠ-6) working width is 6.0 m (only one section of three was used, working width 2.0 m), mass for one metre of working width 300.8 kg. The size of the trial plots was from 12 to 16 m^2. There were four replications of systemic design. The preceding crop was winter wheat. Spaces between the rows of sugar beets were 0.45 m and those between seeds 0.145 m. Sugar beet variety Tivoli (Danisco Seed, Denmark) was used. Soil was loosened with combined cultivator before sowing at 3-4 cm depth. Soil was compacted before and after sowing according to the trial scheme. Fertilization rate was NPK 11:13:30 450 kg ha^{-1} (N_{50}, P_{59}, K_{135}). The additional fertilization was N_{60}. Chemical control of weeds and insects was used.

The soil compaction was measured by Reviakin penetrometer. The field germination of seeds was determined by calculating the plants that emerged in all plots, productivity by weighing the washed roots of sugar beets. Crop density before harvesting was established by counting of all plants in each plot. The quality of sugar beet roots was investigated by express methods in the laboratory of Danisco Sugar Kedainiai sugar factory.

Weather data: In 2007 conditions were favourable for sugar beet crop establishment. In May-August amount of precipitations was higher than average of 1974-2007. However, conditions of seed germination were not favourable as the soil was too dry. Regime of temperatures was higher than average during the whole season of vegetation.

Results and Discussion

Pot experiment: The first sprouts of sugar beet were observed 11 days after sowing. Upper layer seedbed soil bulk density influenced on dynamics of sugar beet seed germination (r = -0.624**). The most rapid sugar beet seed germination was in the seedbeds of 1.0 Mg m^{-3} soil bulk density (Fig. 1).

According to earlier investigations [9], the most favourable soil bulk density for sugar beet seed germination is 0.8-0.9 Mg m^{-3}. Final observation of seed germination showed that the optimal soil bulk density for sugar beet seed germination was from 1.0 to 1.1 Mg m^{-3}. There were 38-40% of sugar beet seeds sprouted over 8 days after the first observation (Table 1).

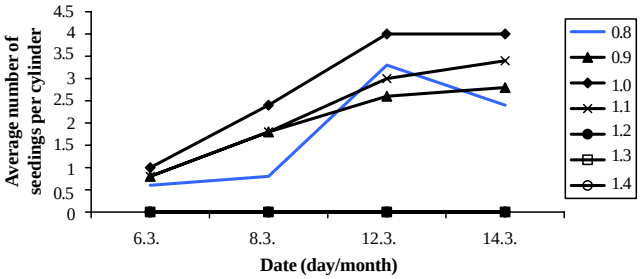

Figure 1. The influence of soil bulk density (Mg m^{-3}) on dynamics of sugar beet seed germination.

Table 1. Sugar beet seed final germination.

Soil bulk density Mg m^{-3}	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Final seed germination %	26	26	38	40	0**	0**	0**

Notes: ** significant difference from control treatment at 99 % probability level. Control treatment is 0.8 Mg m^{-3} of soil bulk density. LSD_{01} = 19.512.

The margin of optimal soil bulk density was very short. In conditions of 1.2 Mg m^{-3} soil bulk density the first sugar beet sprouts were observed about 30 days after the first observation (data are not presented). Soil bulk density of 1.3-1.4 Mg m^{-3} was critical for seed germination. We did not observe any sprouts in late periods.

Field experiment:

Soil physical properties and seed germination: The most compacted seedbed layer (1-4 cm layer) was observed after soil rolling by Cambridge roller before sowing (Fig. 2).

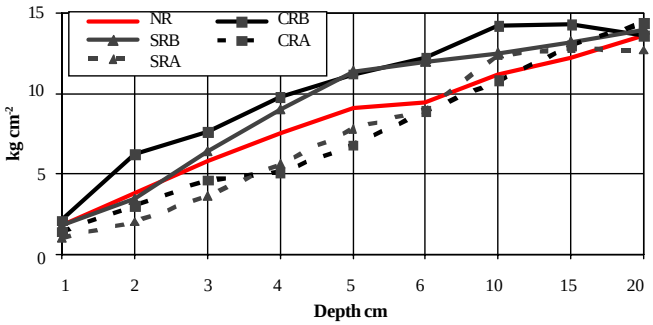

Figure 2. The influence of soil rolling on its compaction. NR-no rolled soil (control); CRB-soil rolled by Cambridge roller before sowing; SRB-soil rolled by spur roller before sowing; CRA-soil rolled by Cambridge roller after sowing; SRA-soil rolled by spur roller after sowing.

Soil rolling after sowing influenced lower compaction level because of lower moisture content in the soil. The gravimetric soil moisture content in seed zone depended on soil compaction properties and varied from 12.8 to 17.8% (data are not presented). The highest moisture content was observed in no rolled soil (17.8%) and rolled before sowing soil (15.3-15.5%). Moisture content in the soil had stronger influence (r = 0.785**) on seed field germination than its compaction level or other seedbed properties (for example, correlation between seed germination and evenness of seedbed down r = -0.490). So, the highest seed field germination was observed in wet no rolled soil (Table 2).

High seed field germination mostly influences on final density of crop (r = 0.709**) [12]. In our presented experiment this influence was not so clear. The soil rolling by Cambridge roller before and after sowing had negative influence on seed field germination (early observation), however, final density of crop was higher than in no rolled soil. It means that some of seeds were sprouted later, after observation.

Sugar beet yield and quality: The highest yield of sugar beet roots (63.57 t ha^{-1}) was found in the plots rolled by Cambridge roller after sowing, it was significantly higher than in no rolled plots (Table 2). In other trials the density of crop could be the main factor influenced on yield of sugar beet roots [7, 12, 13]. In our trial the variation of sugar beet crop density was not so high (from 64 to 93 thousands plants ha^{-1}); and influence of crop density on yield of roots was low (r = 0.303). Generally, soil rolling by Cambridge roller after sowing positively affected on sugar beet root raw material quality too. In such compacted soil root crops had higher amount of sucrose and less amounts of potassium and alpha amino nitrogen.

Table 2. The quantitative and qualitative parameters of sugar beet crop.

Rolling time and method	Seed germination (%)	Density of crop (ths. plants ha^{-1})	Yield of roots (t ha^{-1})	Sucrose content (g kg^{-1})	Potassium content (mmol kg^{-1})	Sodium content (mmol kg^{-1})	Alpha amino nitrogen content (mg kg^{-1})
NR	59.68	77.09	57.90	161.8	41.6	2.7	265.8
CRB	56.46	82.58	63.10	161.4	42.6	2.6	290.8
SRB	55.45	76.54	60.78	164.8	42.0	2.3	289.1
CRA	55.38	82.03	63.57*	168.0*	41.5	2.8	264.8
SRA	53.25*	72.43	56.25	163.5	41.9	3.0	265.0
LSD_{05}	4.916	11.172	5.584	60.00	2.79	1.35	42.14

Notes: * significant difference from control treatment at 95 % probability level. NR no rolled soil (control); CRB soil rolled by Cambridge roller before sowing; SRB soil rolled by spur roller before sowing; CRA soil rolled by Cambridge roller after sowing; SRA soil rolled by spur roller after sowing.

Conclusions

According to the results of the pot experiment, the most rapid sugar beet seed germination was in the seedbeds of 1.0 Mg m^{-3} soil bulk density. The optimal soil bulk density for final sugar beet seed germination was from 1.0 to 1.1 Mg m^{-3}. Seed germination was 46 and 54% higher than in the soil of 0.8-0.9 Mg m^{-3} density. In conditions of 1.2 Mg m^{-3} soil bulk density, seeds sprouted 30 days later and in 1.3-1.4 Mg m^{-3} seeds were not sprouted.

In field experiment the most compacted seedbed layer (1-4 cm layer) was observed after soil rolling by Cambridge roller before sowing (CRB). Soil rolling later (after sowing) affected lower compaction level and higher soil moisture losses. The highest sugar beet seed field germination (56.98%) was observed in wet no rolled soil, it was 5.4-10.8% higher than in rolled plots. Generally, soil rolling by Cambridge roller after sowing (CRA) positively affected sugar beet root yield and quality.

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