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PLANT RESPONSE TO SURFACE CRUST

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A b s t r a c t. Series of model laboratory experiments were performed on loess soil to recognize the relationship between the mechanical impedance of an artificially formed surface soil crust and the emergence of various cultivable plants (cereals, root crops and vegetables). The following sequence of plants was established basing on their decreasing sensitivity to the surface crust strength at the time of emergence:

Sugar beet (cv. PN Mono 4) > parsley > spring barley (cv. ARS) > carrot > sugar beet (cv. PN Mono 1) > tomato > red beet root > french beans > reddish > cucumber > soybeans > maize > spring wheat > spring barley (cv. Diva) > winter wheat > oats > rye > spinach > triticale.

K e y w o r d s: surface crust, plant response

INTRODUCTION

Soil surface crusting is becoming recognized as a phenomenon that is widespread in cultivated fields in various physiographic regions [9]. Crusts sharply reduce infiltration and seedling emergence and can increase the potential for erosion and surface runoff of chemicals [4-6,10]. Recent literature of the subject provides much deeper explanation of the chemical and physical processes involved in the formation of soil crusts than explains the relationships between soil crusting and plant emergence and growth [2,7,8,10].

The purpose of this paper is to bring some information on the response of various plant species to surface crust impedance during emergence.

MATERIALS AND METHODS

A lessive soil (Orthic Luvisol), derived from loess-like material, has been chosen for model laboratory experiments. This soil very often undergoes surface crusting, particularly in the spring time, in climatic conditions of Poland. The soil is characterized by the following features: grain size distribution - sand - 8 %, silt - 51 %, and fine particles - 41 % (including 9 % of clay fraction); pH in 1 N KCl - 6.5; humus content (acc. to Tiurin) - 1.63 %; H_h, S, and T_h - 1.27, 21.4, and 23.8 meq/100 g of soil, respectively; maximum water capacity (pF 0) - 37 % w.w.; modulus of rupture (acc. to Richards) - 57 kPa.

The soil samples were taken from the top 10 cm of the plough layer. After air-drying the soil was sieved through a sieve of 2 mm in diameter. Then special metal containers of the size 20 x 20 x 10 cm (with perforated bottom) were filled thoroughly with the sieved soil to a constant density of 1.5 Mg m^{-3}. A limited number of seeds was placed at a proper depth of sowing for an individual plant species. Four soil containers were designed for each plant: one for control test, i.e. without surface crust and the other three were subjected to a special procedure to create the crust. The soil containers were exposed for an artificial rain under the laboratory rainfall simulator and sprinkled for about 15 min with the rain intensity of 45 mm/h (drop forming units - 3 mm in diameter, falling height - 2.25 m, kinetic energy - 19.5 J m^{-2} mm^{-1}). Then, wet soil samples were exposed to sunshine and infra-red lamps for drying. When the surface crust was ready all the containers (rained and non-rained) were placed on a wet sand layer for moistening, by capillary rise, up to the seed layer. At the time the water front reached the seeding layer the boxes were removed from the sand box to break the water rise. In the following days the number of germinating plants was counted and the penetration resistance of the layer over the seeds was measured daily, both in the crusted and non-crusted samples. The laboratory self-recording needle penetrometer with a 2 mm cone steel probe (30 °) was used for the measurements. It was proved by other authors that the force required to penetrate a soil crust from above may be also used as a measure of the resistance encountered by emerging seedlings [1,3].

RESULTS AND CONCLUSIONS

Data presented in Table 1 prove that the procedure applied to form artificial soil crust in the laboratory conditions creates nearly similar, to some extent, conditions for seed germination and seedling emergence. Obviously, significant differences were recorded between non-crusted and crusted samples, although in the case of the former the values of the penetration resistance were so low that they did not practically limit the seedling emergence.

The average values of the penetration resistance of a 2 cm thick crusted surface layer ranged from 90 to 120 kPa. Hence, it

Table 1. Mechanical impedance of a 2 cm surface layer on crusted and non-crusted soil and plant germination on crusted soil (given as relative values in relation to germination on non-crusted soil assumed as 100 for individual plant species)

Plant species	Mechanical impedance (kPa)		Seedling emergence on crusted soil (rel. value)
	Crusted	Non-crusted	
Root crops			
Carrot	105.8	19.9	19
Parsley	114.6	21.1	10
Red beet	117.0	18.7	30
Reddish	101.1	25.8	35
Sugar beet			
cv. PN Mono 1	117.2	20.3	10
cv. PN Mono 4	103.3	26.3	8
Cereals			
Maize	114.3	21.3	42
Oats	107.4	23.2	72
Rye	110.6	19.7	81
Spring barley			
cv. ARS	108.3	19.4	18
cv. Diva	101.8	24.3	62
Spring wheat	95.7	19.8	49
Triticale	103.9	20.6	91
Winter wheat	118.3	18.0	69
Other crops			
Cucumber	117.7	17.4	37
French beans	120.1	18.1	30
Soybeans	110.5	19.8	39
Spinach	114.3	21.9	89
Tomato	99.5	21.4	24

may be assumed that the crust formed under rainfall simulator was characterized by similar mechanical properties. This, in turn, allow us to evaluate the response of plants' emergence to soil surface crusting.

In the case of non-crusted soils the differentiation of seedling emergence (ranging from 80 to 100 %) has been mainly caused by other, not controlled in this experiment, factors. It might be either seed germination ability or soil air-water conditions. In this series of experiment the poorest plant emergence was noted in case of sugar beet (cv. PN Mono 1), parsley, soybeans and rye.

Very interesting data have been obtained on crusted soil. Here, the mechanical impedance of the surface crust appeared to be a very strongly limiting factor for seedling emergence. The most sensitive plant to surface crusting was one of the tested sugar beet variety - PN Mono 4 from root crops, parsley from among the vegetables tested and spring barley (cv. ARS) from among cereals.

T a b l e 2. Sensitivity of various plant species to mechanical impedance of a surface soil crust (Sequence arranged according to decreasing sensitivity)

Sugar beet	Sensitive to crusting
Parsley	↓
Spring barley (cv. ARS)	
Carrot	
Tomato	
Red beet	
French beans	
Reddish	
Cucumber	
Soybeans	
Maize	
Spring wheat	
Spring barley (cv. Diva)	
Winter wheat	
Oats	
Rye	
Spinach	
Triticale	Not sensitive

On the basis of the number of emerged seedlings and the penetration resistance values of the crust the sequence of plants according to their sensitivity to crusting can be arranged as presented in Table 2.

Worth noticing is also the response of different varieties of the same plant species, as it was found in the case of sugar beet and spring barley. However, this fact can not be expalined yet on the basis of the experiments described in this paper. The results discussed here are introductory and further research to explain the above phenomenon is required on the background of controlled water-air conditions and biological tests.

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