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Trg Dositeja Obradovića 8, 21000 Novi Sad, R. Serbia
Tel.: +381 21 485-3477; Fax : +381 21 6350-019;
www.contagri.info contagri@polj.edu.rs

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TEST ON THE EFFECTS OF RECONSTITUTED SOIL ON EMERGENCY SPEED AND ROOT GROWTH IN MAIZE*

Paolo MANFREDI[1], Chiara CASSINARI [2♦], Roberta SALVI, Raffaella BATTAGLIA[3], Adriano MAROCCO[2], Marco TREVISAN[2]

***Summary:** Reconstitution is a pedotechnique to counter land degradation and desertification. The reconstitution, patented by the research laboratory m.c.m. Ecosistemi, applies chemical-mechanical actions to a mixture of degraded soil and matrices (such as waste sludge) in order to produce reconstituted soil, a very high fertility soil. This paper is about a pot study in a greenhouse to investigate how reconstituted soil affects emergence speed and seminal roots development of Zea mays L. seedlings, in comparison with a Technosol. 200 seedlings are monitored up to the 16th day after the seeding. The emergence percentage is 98% on reconstituted soil and 91% on Technosol. Average length and weight of fresh seminal roots are higher on reconstituted soil.*

***Keywords**: reconstituted soil; maize; seminal roots development; emergence*

INTRODUCTION

Soil could be considered a non-renewable resource, it gives essential functions and ecosystem services (Lal, 2012; Popović, 2010; 2015). Nowadays, soil degradation is a serious and worldwide issue (European Commission COM (2006) 231). Degradation causes chemical and physical alterations of soil: loss of structure leading to compaction, decreasing in organic matter, reduction in soil organisms and biodiversity (Holland, 2004), salinization,

[1] Paolo Manfredi, Dr, m.c.m. Ecosistemi srl, località Faggiola, 29027 Gariga Podenzano, Italy,
[2]Chiara Cassinari, Dr, Facoltà di Scienze Agrarie, Alimentari e Ambientali, Dipartimento di Scienze e Tecnologie Alimentari per una filiera agro-ambientale Sostenibile - DiSTAS, Università Cattolica del Sacro Cuore, via E. Parmense 84, 29122 Piacenza, Italy,
Roberta Salvi, Dr, Dipartimento di Scienze delle Produzioni Vegetali Sostenibili, Università Cattolica del Sacro Cuore, via E. Parmense 84, 29122 Piacenza, Italy,
[3]Raffaella Battaglia, Dr, CREA, Consiglio per la ricerca e l'analisi dell'economia agraria, Genomics Research Centre, via S. Protaso 302, 29017 Fiorenzuola d'Arda Piacenza, Italy,
Adriano Marocco, Professor, Dipartimento di Scienze delle Produzioni Vegetali Sostenibili, Università Cattolica del Sacro Cuore, via E. Parmense 84, 29122 Piacenza, Italy,
Marco Trevisan, Professor, Facoltà di Scienze Agrarie, Alimentari e Ambientali, Dipartimento di Scienze e Tecnologie Alimentari per una filiera agro-ambientale Sostenibile - DiSTAS, Università Cattolica del Sacro Cuore, via E. Parmense 84, 29122 Piacenza, Italy
♦ Corresponding author: chiara.cassinari@unicatt.it orcid.org/0000-0002-1652-6766

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elemental imbalance, acidification and decline in soil structure (Lal, 2012). These elements contribute to a significant amount of soil quality depreciation annually. Excessive soil degradation thus gives rise to immediate and long-term impacts which translate into serious global environmental headaches.

The major drivers of soil degradation are climate aridization (D'Odorico et al., 2013), unsustainable agricultural practices, industrial and mining activities (Dudka and Adriano, 1997), expansion of crop production to fragile and marginal areas (Shangguan et al. 2014), inadequate maintenance of irrigation and drainage networks, and overgrazing (Hooke et al., 2012; Krasilnikov, et al., 2016).

Mining activities disrupt aesthetics of the landscape along with disrupt soil components such as soil horizons and structure, soil microbe populations, and nutrient cycles those are crucial for sustaining a healthy ecosystem and hence results in the destruction of existing vegetation and soil profile (Kundu and Ghose, 1997).

To counteract degradation, most studies focus on suggesting alternative managements of soil. Rarely researches focus on looking for technologies able to generate fertile soil from degraded one also using waste matrices (Manfredi et al., 2012). In this perspective, the Life + project New Life (LIFE10 ENV/IT/000400), co-financed by European Union, aims to test an innovative technology to restore degraded soil, the reconstitution - patented by research laboratory m.c.m. Ecosistemi. Reconstitution applies, to a mixture of degraded soil and waste matrices, chemical and mechanical actions affecting soil texture, density and organic matter, resulting in reconstituted, a very high fertility soil (Manfredi, 2016). The core of reconstitution is the addition of organic matter within the soil mineral fraction. Reconstitution is suitable in different soil conditions: soils which undergone modifications of their original conditions (as an example mining activities, a Technosol), or areas subjected to unsustainable agricultural practices (Manfredi, 2016).

In 2012 agronomical properties of reconstituted soils were investigated through a test with maize (*Zea mays* L.) grown up on Technosol (Rossiter, 2007) versus reconstituted soil, managed with the same amount of fertilizer but different amount of irrigation water. The results showed high yields on reconstituted soil, saving 45% of irrigation water (Manfredi et al., 2012).

The experiment in this paper is a further investigation - using maize, in pots and greenhouse conditions - with the same soils used for the test above - in order to evaluate the effects of the two different soils on plant emergence and seminal root development.

MATERIAL AND METHODS

Soil

Soils used in the experiment were collected from a farm in Gossolengo (45°01'02''N 9°36'32''E, Piacenza, Emilia Romagna, Italy). The farm soil is the result of backfilling after an extraction activity of gravel and can be said Technosol. Refilling, in 1980, was performed with silty clay soil from nearby hills, and partially with waste from sugar industry (defecation calcium) (Manfredi, 2016).

In 2008 a farm plot is reconstituted, and so currently the farm is divided in 2 plots: Technosol plot and reconstituted soil plot.

The soils used in pot experiment were sampled from Technosol, thesis A, and reconstituted soil, thesis B.

Soils were characterized: physico-chemical analyses were performed on 3 Technosol samples and 3 reconstituted soil samples. Characterization was made on air-dried < 2 mm soils, according to the Official Italian procedures (MiPAF 2000). Sand (2.0 - 0.02 mm), silt (0.02 - 0.002 mm) and clay (< 0.002 mm) fractions were separated by hydrometer. Volumetric water content was determined using Richard plates. pH was measured on 1:2.5 soil/water suspension. Total C was measured by flash combustion. Organic C was oxidized with dichromate potassium and titrated (Walkley-Black, 1934). Total N was measured by Kjeldahl procedure.

Experimental Set Up and Plant analysis

Maize (*Zea mays* L.) used was a hybrid *Antiss* by the company Limagrain Italia S.p.A.

50 pots (V: 71.45 cm^3) were used for each thesis. Pots were filled with soil and levelled in order to create a proper seedbed at 2 cm deep. For each pot 2 seeds were placed along the diagonal and they were spaced 5 cm from each other, so 100 seeds were used for each thesis. Pots were placed in a greenhouse, in 10 rows by 5 pots; every row is considered a replica of the thesis (10 replicates). The average temperature in nursery was 25 °C. Water was provided in the same amount for all the pots, following need of Technosol: immediately after seeding (250 ml) and, the second (250 ml), the sixth (100 ml), the ninth (100 ml), the tenth (150 ml), the thirteenth (100 ml), the fourteenth (100 ml) and finally the fifteenth (100 ml) days after seeding. Daily measurements in each pot included day of

emergence of each seedling and total number of plants emerged. At the end of the study the total emergence percentage was calculated. Every plant was harvested manually at 16 days from seeding. Soil was gently removed from root system with water and to refine the cleaning any residual were carefully removed from each root by hand. Afterward root system was removed from shoot with a sharp blade, and measurement of length and weigh were taken.

Statistical Analysis

The log-transformed root length and plant's fresh weight data were statistically analysed by Analysis of Variance (ANOVA). When necessary, inverse variance weights $W=1/S^2$ (where W and S^2 were the weight and the sample variance computed for Technosol and reconstituted soil respectively) were introduced in the ANOVA linear model fitting in order to account for variance heterogeneity. The data Analysis was performed by R 3.2.1 base and car packages.

RESULTS

Soil

Reconstitution affects soil chemical properties (Table 1), but doesn't affects soil pH and texture. The main differences occur on total and organic carbon and total nitrogen content.

Table 1. Physico-chemical analysis of soils, mean ± SD

	sand	silt	clay	pH	tot. C	org. C	tot. N
	g kg^{-1}	g kg^{-1}	g kg^{-1}		g kg^{-1}	g kg^{-1}	g kg^{-1}
A	355 ± 44	498 ± 45	147 ± 15	8.1 ± 0.1	35.5 ± 2.2	12.1 ± 0.6	1.87 ± 0.38
B	330 ± 87	563 ± 89	107 ± 90	7.9 ± 0.1	67.1 ± 10.3	43.9 ± 4.2	3.93 ± 0.42

A: Technosol; B: reconstituted soil

The total carbon and nitrogen content in thesis B was twice as high as in thesis A, while the content of organic carbon was 3 times higher in B than A.

The Volumetric water content (%) was higher in thesis B than in thesis A (Table 2), that means more available water for plant in reconstituted soil.

Table 2. Volumetric water content (%) at different suction (-kPa), and available water, mean ± SD

	suction (-KPa)		
	31.6	1496.2	
	field capacity	wilting point	available water
A	35.4 ± 2.1	30.2 ± 1.8	5.1 ± 1.2
B	40.1 ± 5.3	33.1 ± 5.8	7.0 ± 0.9

A: Technosol; B: reconstituted soil

Plant Emergence

Emergence takes place in 4 days after seeding, both in thesis A and B, but during the test remarkable differences are observed. The most important differences are on germination rate, which is faster in thesis B, as it is showed in Figure 1.

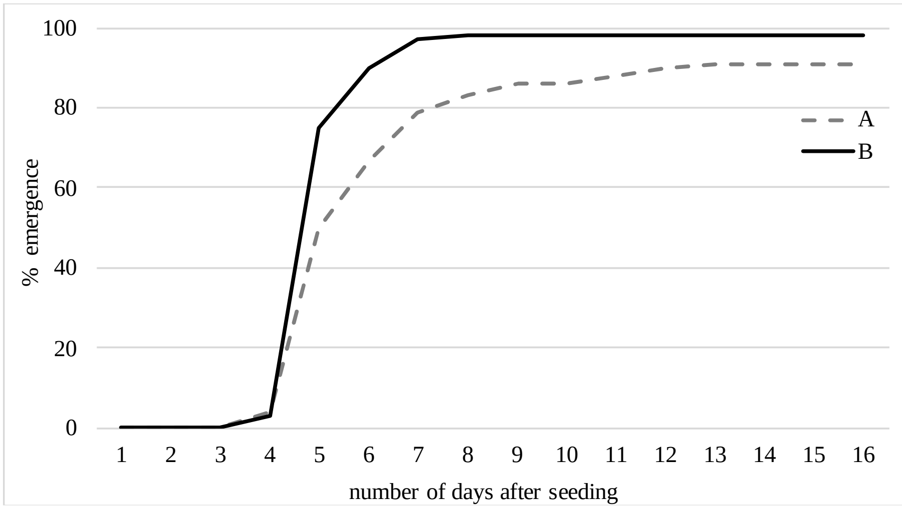

Figure 1. Emergence (%), A: Technosol; B: reconstituted soil

In thesis A, at 6 days after seeding the percentage of emergence is 67%, at 12 days after seeding is 90%; the percentage at the end of the test is 91% (Table 3). In thesis B, at 6 days after seeding the percentage of emergence is 90%, at 12 days after seeding is 98%; the percentage at the end of the test is 98% (Table 3).

Table 3. Emergence (%), length (cm) and weight (g), mean of 50 plants, mean ± SD

	emergence %	lenght cm	weight g
A	91	27.7* ± 12.3	1.3 ± 0.6
B	98	31.1* ± 8.0	1.6 ± 0.7

A: Technosol; B: reconstituted soil. * indicates statistically difference P < 0.05

Plant Development

At 16 days after seeding seminal root system (primary and the seminal roots) are developed and young adventitious crown roots have arisen from stem tissue both in thesis A and thesis B. Differences between the thesis concern the mean length of the longest seminal root and the mean weight of the complete root system. The average length of the longest seminal root was statistically different ($P < 0.05$) between thesis A and thesis B, i.e. higher in B than in A (Table 3 and Figure 2).

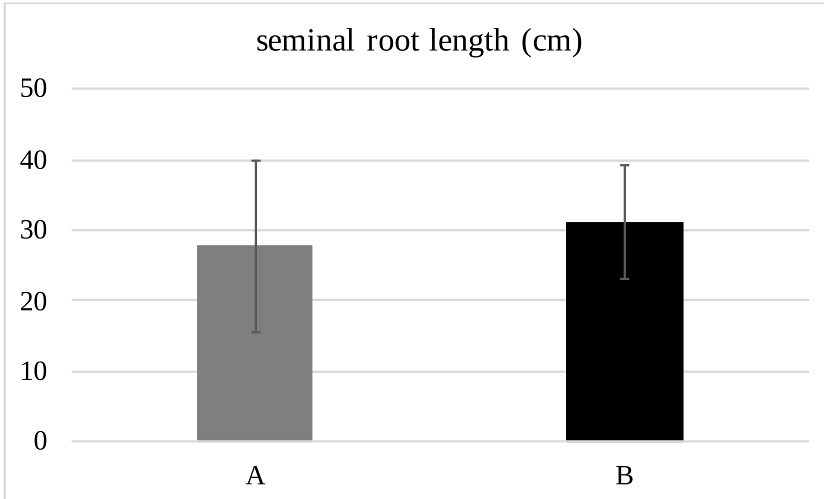

Figure 2. System root length (cm), mean of 50 plants (histogram) and standard deviation (bar), A: Technosol; B: reconstituted soil

The average weight of whole root system (seminal root systems and initial whorl of adventitious roots) was statistically different ($P < 0.05$) - heavier in B, than in A (Table 3 and Figure 3).

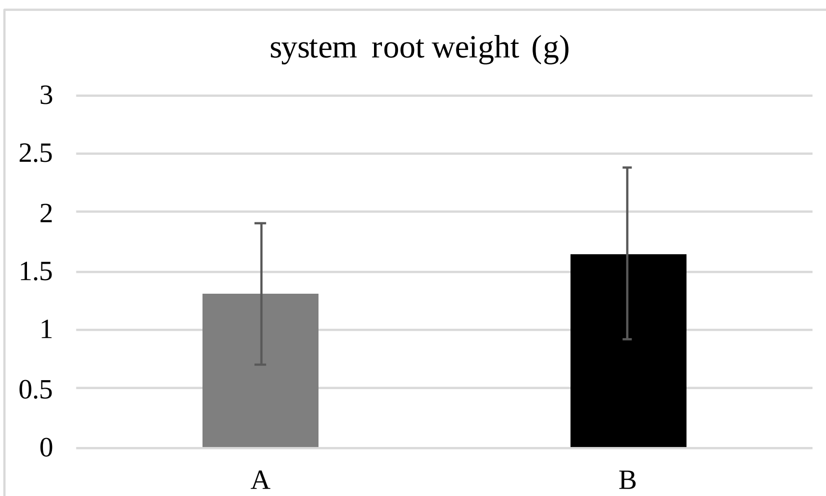

Figure 3. Seminal root weight (g), mean of 50 plants (histogram) and standard deviation (bar), A: Technosol; B: reconstituted soil

DISCUSSION

Reconstitution Technology Effects on Technosol

Reconstitution positively affects Technosol: increasing total and organic carbon and total nitrogen and improving hydrological properties (Table 1). Mamman et al. (2007) and Holland (2004) demonstrated that soils with high levels of organic matter present better structure, improved soil aeration and water retention properties. Soil with high value of organic matter stands up against compaction more than soils with low organic matter, restraining problems of physical degradation that is one of the most dangerous conditions for the development and growth of crops such as maize (Mamman et al., 2007; Ohu et al., 2009; Singh et al., 2014). Manfredi (2016) describes how reconstitution is able to decrease bulk and particle density of a Technosol increasing soil porosity. These changes in reconstituted soil are very important in relation to root development. It has been demonstrated, that compaction has negative effects on seed emergence and crops yield. In addition, mechanical penetration resistance and poor aeration restricts root growth, both seminal and adventitious root system, and increase penetration resistance to root configuration, which especially affects the uptake of nutrients and negatively influence fertility (Braunack, 1994; Mamman et al., 2007; Singh, 2014).

Effect of Reconstituted Soil on Plant Emergence

Reconstitution has favourable effects on plant emergence. The rate and emergence percentage in reconstituted soil can be explained by better hydrological properties. In fact, water availability and temperature - soil temperature is related to water content - are the primary conditions that influence seed and rate germination. Water is the first limiting factor to break dormancy of the seed (Kiesselbach, 1999) and it has been demonstrated that substrates with better water availability have faster and better germination (Kiesselbach, 1999).

Also, compaction and soil strength could influence emergence, increasing the mechanical penetration resistance the coleoptile finds to reach the surface (Kiesselbach, 1999; Braunack, 1994; Singh, 2014). It has been showed that soil strength decreases with increasing soil water content, and soil bulk density decreases with increasing in organic matter and both soil water content and aggregated size significantly affect the emergence of crops, such as soybeans and maize (Braunack, 1994; Mamman et al., 2007).

Effect of Reconstituted Soil on Root Development

In maize lateral roots are responsible for the uptake of water and mineral components, while main seminal and nodal roots are responsible for distribution of lateral roots in the soil profile and water transport to green plant parts (Grzesiak et al., 2014). It is clear that any deficit in their development may influence negatively maize plant growth, affecting on yield. A balance soil structure - due to high organic carbon content - is required to ensure better contact between soil particles and seeds.

According with our research is Manfredi et al. (2012), in field experiment they proved that reconstitution improves soil fertility with positive effects in plant emergence, root development and plant yield in maize.

CONCLUSION

Chemical and physical properties of Technosol are improved after reconstitution. Reconstitution affects positively hydrological properties, carbon and nitrogen content. Good hydrological properties and high organic carbon content mean less mechanical opposition for roots development.

This experiment prove that reconstitution improves soil fertility with positive effects in plant emergence, root development and plant yield in maize.

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