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X-RAY STEREOSCOPIC RADIOGRAPHS OF MACROPORE STRUCTURES FORMED BY THE ROOTS IN GRASSLAND SOILS

K. Sato, Y. Sato, and T. Moroizumi
School of Veterinary Medicine and Animal Sciences, Kitasato University, Towada, Aomori 034, Japan

ABSTRACT

The objective of this study was to examine the morphology of macropores with respect to drainage and water-retention in the root zones under grassland soils. Soil samples were taken in Japan, the U.K. and China. The structures of macropores were studied three-dimensionally by examining the macropore morphology using X-rays and contrast media. The pore morphology studied in grassland soils indicate that the shapes of most macropores in drainage and water-retention pores were formed by roots. The pores formed by grass roots were found to play an important part in the macropore forms found in grassland soils.

KEYWORDS

Andosol, Brown forest soil, Chestnut soil, Weathered granite soil, Grassland soil, Macropore, Soil structure, X-ray.

INTRODUCTION

The macropores of permanent grassland soils function to drain and hold water. The macropores help increase agricultural productivity and preserve the environment. However, macropore morphology in permanent grassland soils has not been researched extensively. Previous investigations of macroporous soil structures using X-rays have been conducted byHamblin(1962), Bouma(1969), and Rogaar(1975). Analyses of these studies have yet to explain the effects of soil structure because X-ray are only effective up to a soil thickness of 5 mm. More recently, Tokunaga et al.(1984) found contrast media suitable for using X-rays on soil pore structures. This method enabled the use of X-rays for samples more than 40 mm thick. By using this method, Sato(1991,1992,1993) determined that most macropores in permanent grassland soils were formed by grass roots. These studies clarified that the macropore morphology of drainage and water-retention pores formed by grass roots under the different soil, weather and vegetation conditions in grassland areas is a natural phenomenon.

METHODS

Soil Sampling. Soils samples were taken in Japan (Andosol: volcanic sandy soil, weathered granite soil: sandy soil), China (Chestnut soil: steppe sandy soil), and the U.K.(brown forest soil: clay soil). The soil samples were collected from grassland root-zone layers less than 85 cm deep.

Test Material and Adjustment. The structures of macropores were studied three-dimensionally by examining the macropore morphology using X-rays and contrast media. The pore forms were soaked in a contrast media solution to facilitate in photographic examination using X-rays. Sample trimmed to 4.2 cm square were arranged for processing, with the test material side of samples reinforced by a clay coating. The samples were subsequently saturated with water through a vacuum saturation process. Soil moisture conditions at the drainage pores (pF0, pF1.2) and water-retention pores (pF1.8, pF2.0) were then adjusted. The trimmed samples were finally soaked in a contrast media solution (CHÇQIÇQ) to facilitate photographic examination using three dimensional photographic
methods.

Photography. X-ray photographs of tube voltage between 60 to 70 kVp at 3 mA were taken using Fuji #150 film with a radiation exposure time of 70 to 80 seconds. The photographs were taken using three-dimensional photographic methods.

Physical Properties of Soil and Measurement. The physical properties of the soil (i.e., texture, bulk density, permeability and three-phase distribution) were measured using Japanese Industrial Standards (JIS) measurement system.

RESULTS AND DISCUSSION

Physical Properties. The layers of Andosol, weathered granite soil and Chestnut soil had a sandy, loamy texture. Brown forest soil had a clay like texture. Weathered granite soil, chestnut soil and brown forest soil were dense and solid, with solid phase rates of 46 to 58%. Conversely, Andosol had a much lower rate (Table 1). Macropores and available pores in the surface layer of Andosol and weathered granite soil were small, and the permeability low. The micropores, however, were large. In the surface layer of brown forest soil and granite soil, the macropores and available pores were large with high permeability, but the micropores were small. The macropores, available pores and permeability increased in the subsoil layer of Andosol and weathered granite soil, but decreased in the subsoil layer of brown forest soil.

Andosol. The morphology of non-capillary pores (pF - 1.5: drainage pores), and macropores in the surface layers (0-10 cm) developed irregularly in the horizontal and diagonal directions along cracks, instead of vertically. In the subsurface layer (10-35 cm), thicker pores developed in the vertical direction at a constant distance, with thinner pores clearly developed in the horizontal direction from the thick pores. In the subsoil layer (40-55 cm), the pore morphology was not formed by grass roots, instead, it originated from previously planted grass. The morphology of capillary pores (pF1.8, pF2.0: water-retention pores) was shaped by pores formed by roots and pores outside the particles and aggregates.

Weathered Granite Soil. The morphology of non-capillary pores (pF - 1.5) is classified by each layer of soil. The surface layer (0-10 cm) consisted of pores formed by grass roots. The subsurface layer to the subsoil layer (10-45 cm) consisted of pores formed by roots, and pores outside the particles and aggregates. The capillary pores (pF1.8, pF2.0) were shaped by pores formed by roots in the surface layer. Another subsoil layer consisted of pores formed by roots, and pores outside the particles and aggregates. The pore morphology studied in the weathered granite soil indicated that the shapes of most macropores were formed by roots.

Chestnut Soil. The morphology of non-capillary pores (pF - 1.5) originated from cracks, insect burrows and pores formed by roots in the surface layer (0-10 cm), and the subsoil layer (10-60 cm) was shaped by pores formed by roots. The capillary pores (pF1.8, pF2.0) were shaped by pores formed by roots and pores outside the particles and aggregates. The pore morphology studied in the Chestnut soil indicated that the shapes of most macropores were formed by the pores formed by roots.

Brown Forest Soil. The morphology of non-capillary pores (pF - 1.5) was observed in each layer of soil. The surface layer (0-10 cm) consisted mainly of pores formed by earthworm and aggregates. The subsurface layer to the subsoil layers (10-85 cm) consisted of pores formed by roots. The morphology of capillary pores (pF1.8, pF2.0) was shaped by pores formed by roots and aggregates in the surface layer (0-10 cm), and subsoil layers (10-85 cm) was shaped by pores formed by roots. The capillary pores consisted of pores formed by roots. The pore morphology studied in brown forest soil indicated that the shapes of most macropores were formed by grass roots.

In dense clay soil, the macropore morphology studied in drainage and water-retention pores indicated pores formed by grass roots. In sandy, loamy soil, the morphology of drainage and water-retention pores was shaped by pores formed by roots in the dense surface layer. Another subsoil layer consisted of pores formed by roots and pores outside the particles and aggregates. These radiographic images mainly show tubular root pores formed by the contrast media. The pore morphology showed in these radiographic images reveal that the shapes of most macropores were formed by roots. This matched the findings concluded for investigation of Andosol, weathered granite soil, steppe soil and brown forest soil. Therefore, tubular root pores that originate from grass roots play an important part in shaping the macropore structures in grassland soils.

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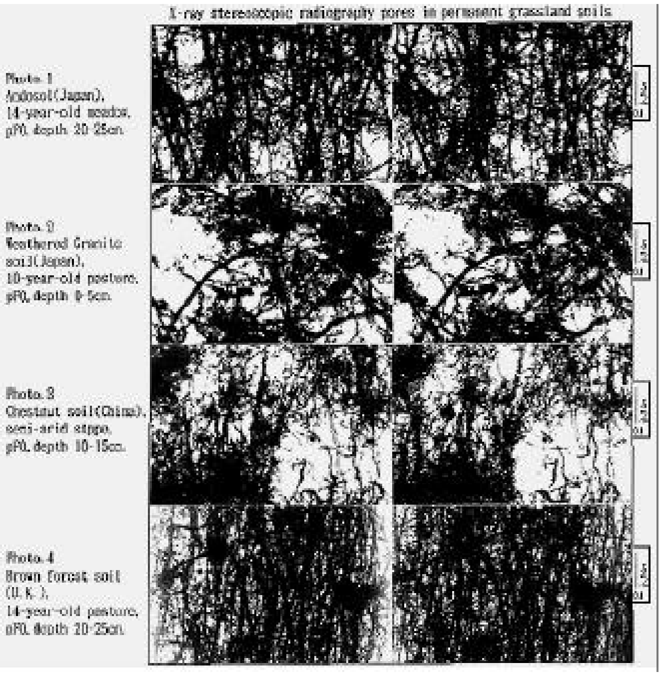

Table 1
Physical properties and radiographic pore diameter in permanent grassland soils.

Soil physical properties									Radiographic pore diameter			
									Non-capillary pore (mm)		Capillary pore (mm)	
Soil name	Depth (cm)	Soil[a] texture (ISSS)	Bulk density (g/cm^3)	Solid phase (%)	Macro-pore (%) (pF-1.5)	Available pore (%) (1.5<pF-2.7)	Micro-pore (%) (pf)2.7	Perme-ability (cm/sec)	pF0	pF1.2	pF1.8	pF2.0
Andosol	0-5	FSL	0.82	34.4	0.8	3.3	61.5	2.00 x 10^{-5}	0.37	0.25	0.19	0.16
	5-10	FSL	0.82	33.7	0.6	8.8	56.9	3.75 x 10^{-5}	0.47	0.26	0.20	0.13
	20-25	LoCS	0.69	27.0	9.1	23.4	40.5	3.75 x 10^{-3}	0.51	0.28	0.14	0.12
	40-45	LoCS	0.69	25.6	23.3	14.5	36.6	1.71 x 10^{-2}	0.78	0.26	0.13	0.11
Weathered granite soil	0-5	LFS	1.39	52.8	7.1	6.1	34.0	1.97 x 10^{-5}	0.46	0.32	0.14	0.12
	5-10	LFS	1.59	58.3	8.0	5.1	28.6	3.26 x 10^{-5}	0.34	0.30	0.15	0.09
	20-25	LFS	1.42	53.5	15.8	7.1	23.6	2.25 x 10^{-3}	0.34	0.29	0.13	0.09
	40-45	LFS	1.39	52.1	15.1	7.4	25.4	5.23 x 10^{-3}	0.35	0.27	0.12	0.08
Chestnut soil	0-5	CoSL	1.41	53.1	7.3	15.6	24.0	7.82 x 10^{-4}	0.81	0.57	0.31	0.18
	5-10	CoSL	1.43	53.7	7.4	18.0	20.9	7.93 x 10^{-4}	0.78	0.62	0.27	0.15
	10-15	CoSL	1.48	55.3	6.3	21.1	17.3	1.73 x 10^{-3}	0.98	0.51	0.18	0.12
	35-40	CoSL	1.40	52.1	5.5	23.5	18.9	1.74 x 10^{-3}	1.04	0.47	0.17	0.13
Brown forest soil	0-5	LiC	1.01	46.0	9.0	6.3	38.7	1.87 x 10^{-3}	0.49	0.39	0.25	0.24
	5-10	CL	1.33	53.0	2.1	4.3	40.6	1.97 x 10^{-3}	0.53	0.47	0.26	0.34
	20-25	SiCL	1.57	58.7	1.8	3.0	36.5	6.26 x 10^{-5}	0.39	0.35	0.29	0.27
	35-40	HC	1.58	55.5	1.7	3.8	39.0	2.09 x 10^{-6}	0.42	0.34	0.29	0.32

a) Soil texture is FSL = fine sandy loam, LoCS = loamy coarse sand, LiC = light clay, CL = clay loam, SiCL = salty clay loam, HC = heavy clay, CoSL = coarse sandy loam, and LFS = loamy fine sand.