

## True versus natural texture of selected soils

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### ABSTRACT

A standard laboratory method involving distilled water and a dispersant is used to determine the true texture of soils, but the results may not reflect the micro-aggregation that can occur when field soils are wetted by precipitation or irrigation water. This study compared the true texture of soils determined by the standard hydrometer (SH) method with the 'natural' texture determined by the hydrometer method without a dispersant using distilled water (H+DW), well water (H+WW), or rain water (H+RW). Soil water retention, aggregate stability, and crust strength as affected by water quality were compared also. Compared to the SH method, the H+DW and H+RW methods indicated more sand and silt and less clay in all soils. In many cases, sand, silt, and clay determined with H+DW and H+RW methods were not different. The H+WW, H+DW, and H+RW methods indicated similar sand contents, but silt was always greater and clay was always zero with the H+WW method. Water retention and aggregate stability were not affected by water quality. Crust strength results were variable. The study indicates that soils under field conditions may behave differently texture-wise than what may be inferred by using the SH method. Hence, true texture determination with the SH method and 'natural' texture determination with a modified hydrometer method using the water that is involved under field conditions is recommended. Such information should be of value when making management decisions that affect soil crusting, which, for example, may affect seedling emergence, water infiltration, and soil erosion.

### INTRODUCTION

Texture is an important soil property that influences many other soil properties, including water infiltration, retention, and conductivity; aggregate size distribution and stability; and erodibility. Because of its importance, a standard laboratory method is used to determine the 'true' soil texture (1) based on particle size distributions (2). The standard method involves using distilled water to which a soil dispersant is added. However, distilled water containing the dispersant usually is vastly different from precipitation and well water. Hence, particle size distributions obtained by using the standard method may not reflect the micro-aggregation that occurs under field conditions when soils are wetted by precipitation or well water.

Ahn (1) determined soil particle size distribution of soils from several horizons using the standard method and a modification of the standard method for which the dispersant was not added. Without the dispersant, apparent sand and silt contents usually were much greater and clay content was much lower than with the dispersant. Ahn (1) referred to the texture determined without adding the dispersant as the 'natural' texture of the soil.

In addition to soil dispersion and, hence, 'natural' texture differences due to water quality, soil dispersion also differs due to water application intensity. Important consequences of soil dispersion are surface sealing and crust development, which strongly influence water infiltration and runoff and, hence, soil erosion (3, 4, 5, 6, 7, 8, 9).

The importance of determining the true soil texture by a standard method is not

questioned. However, soils are wetted by precipitation or well water under field conditions, and it was hypothesized that the texture determined by using rain water or well water would be different from that determined by the standard method. Using different waters also may influence soil water retention, aggregate stability, and crust strength. Hence, objectives of this study were to evaluate the effects of different-quality waters on the sand, silt, and clay content (true or 'natural' texture); water retention; aggregate stability; and crust strength for some selected soils. Such information would be useful for developing management practices for different soils based on whether precipitation or irrigation is the main water source.

### MATERIALS AND METHODS

The study was conducted at the USDA-Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, Texas. Soils for this study were obtained from Major Land Resource Area 77 of the U.S. Southern High Plains. The soil series were:

- Pullman clay loam (fine, mixed, thermic Torreritic Paleustoll),
- Randall clay (fine, montmorillonitic, thermic Udic Pellustert),
- Portales sandy clay loam (fine-loamy, mixed, thermic Aridic Calciustoll),
- Amarillo sandy clay loam (fine-loamy, mixed, thermic Aridic Paleustalf),
- Amarillo sandy loam (fine-loamy, mixed, thermic Aridic Paleustalf),
- Dalhart loamy sand (fine-loamy, mixed, mesic Aridic Haplustalf),
- Dalhart sandy loam (fine-loamy, mixed, mesic Aridic Haplustalf),
- Dumas sandy clay loam (fine-loamy, mixed, mesic Aridic Paleustoll), and
- Sherm clay (fine, mixed, mesic Torreritic Paleustoll).

Different soil horizons were sampled in field or pasture areas to obtain materials having a wide range of sand, silt, and clay content. Samples obtained from three different areas within each field or pasture were treated as replicates for statistically analyzing the data.

The soils were passed through a sieve having 2-mm diam. openings before making the

determinations. Particle size distribution was determined by using the standard hydrometer method (2) and several variations of that method. The methods were:

- SH -- standard hydrometer method using distilled water and sodium hexametaphosphate as a dispersant,
- H + DW -- hydrometer method with distilled water and without dispersant,
- H + WW -- hydrometer method with well water and without dispersant, and
- H + RW -- hydrometer method with rain water and without dispersant.

Except for using different water, the method was the same in all cases. An analysis of the well water is given in Table 1.

Because the H + RW and H + DW methods usually gave similar results regarding soil particle size distributions and use of water as used for the SH method was not practical, other determinations were made only with rain water and well water. Also, these waters are of interest under field conditions. Determinations

Table 1. Analysis of well water, Bushland, Texas.

Constituent	Concentration
Calcium	48.0 mg/L
Chloride	7.0 mg/L
Fluoride	2.8 mg/L
Magnesium	25.0 mg/L
Nitrate (as N)	1.5 mg/L
Sodium	38.0 mg/L
Sulfate	48.0 mg/L
Total hardness/CaCO <sub>3</sub>	224.0 mg/L
pH	8.0
Dil. conductivity	624.0 $\mu$ mhos/cm
Total alkalinity as CaCO <sub>3</sub>	245.0 mg/L
Bicarbonate	299.0 mg/L
Carbonate	0 mg/L
Dissolved solids	328.0 mg/L
P. alkalinity/CaCO <sub>3</sub>	0 mg/L
Iron	0.04 mg/L
Manganese	0.02 mg/L

were soil water retention at -0.033 and -1.5 MPa matric potentials, aggregate stability using 1- to 2-mm diam. aggregates (10), and crust strength (for six soils only).

For inducing crust formation, simulated rainfall was applied to a 2.5-cm thick layer of the soils that was loosely placed over 2- to 3-cm diam. gravel in 10-cm diam. metal containers that had holes in the bottom for draining excess water. An application of 50 mm of irrigation water in 60 min to one set of samples was immediately followed by an identical application of rain water to another set of the soil samples. The simulator was similar to the one described by Merz et al. (11). Water fell from small tubes from a height of 1.7 m, which resulted in a terminal drop velocity of 70% compared to that of natural precipitation. The tubes were spaced 19 mm apart in both directions. An oscillating fan provided slight air movement under the simulator, thus resulting in random points of raindrop impact on the surface.

Crust strengths were determined with a penetrometer (4.76-mm diam. flat point, Model 719-5MRP, John Chatillon & Sons, Kew Garden, NY 11415)<sup>1</sup> after the soils had air-dried in a greenhouse for 48, 96, and 168 h. Ten strength determinations were made at each time of measurement and for each soil.

Data were analyzed by the analysis of variance or paired t-test technique. When mean differences determined by analysis of variance were significant at the 0.05 level of probability, means were separated by the Duncan Multiple Range Test. Separate statistical analyses were performed for each soil and for each time of measurement for crust strength.

## **RESULTS AND DISCUSSION**

### ***Particle size distribution***

Results of particle size distribution determinations are given in Table 2. As compared to results obtained with the SH method, the H+DW and H+RW methods

indicated greater sand and silt contents, and a lower clay content in all soils. In many cases, the indicated sand, silt, and clay contents determined by the H+DW and H+RW methods were not significantly different. Sand content with the H+WW method was similar to that with the H+DW and H+RW methods, but that of silt was always greater and that of clay was always zero with the H+WW method. These trends were similar to those reported by Ahn (1) in that the indicated sand and silt contents were greater and clay contents were lower with H+DW and H+RW methods than with the SH method. Even greater sand and silt contents and zero clay contents were obtained with the H+WW method. In no case was a zero clay content reported by Ahn (1). His clay contents ranged from 0.5 to 11.3% when no dispersant was used. With dispersant, they ranged from 45.2 to 68.5%. Complete 'disappearance' of clay from soils with the H+WW method was not expected. Well water apparently contained adequate Ca to prevent dispersion of soil aggregates.

### ***Water retention***

Water retention at matric potentials of -0.033 and -1.5 MPa for a given soil was not affected by water quality at the  $P = 0.05$  level of significance (Table 3). However, for all soils at -0.033 MPa potential, retention values were 0.8 to 1.7 percentage units greater with rain water than with well water, which suggested that soil dispersion probably was slightly greater with rain water. With greater dispersion, mean pore sizes are smaller, thus resulting in greater resistance to water removal at the smaller negative potential. At -1.5 MPa potential, numerical water retention values due to water quality were 0.5 to 2.0 percentage units greater with rain water than with well water for soils having the greater clay contents (Pullman, Randall, and Sherm) and 0.2 to 0.4 units lower with rain water than with well water for the sandier soils (Portales, Amarillo, and Dalhart). These trends, again, suggested greater soil dispersion with rain water than with well water. Soils with greater clay contents retain more water when dispersed whereas sandier soils would be less affected by soil dispersion. These trends in water retention, although not

<sup>1</sup> Mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

**Table 2. Effects of method of determination on sand, silt, and clay contents and texture of selected U.S. Southern High Plains soils.**

Soil and original texture <sup>a</sup>	Method <sup>b</sup>	Soil particle			Determined texture <sup>c</sup>
		Sand	Silt	Clay	
		----- % -----			
Pullman clay loam	SH	14 b <sup>d</sup>	40 c	46 a	Clay
	H + DW	25 a	55 b	20 b	Silt loam
	H + WW	27 a	73 a	0 c	Silt loam
	H + RW	27 a	55 b	18 b	Silt loam
Randall clay	SH	5 c	24 c	71 a	Clay
	H + DW	19 a	40 b	41 b	Clay
	H + WW	17 b	83 a	0 c	Silt
	H + RW	18 ab	41 b	41 b	Silty clay
Portales sandy clay loam	SH	16 b	36 d	48 a	Clay
	H + DW	30 a	44 c	26 b	Loam
	H + WW	30 a	70 a	0 d	Silt loam
	H + RW	30 a	50 b	20 c	Loam
Amarillo sandy clay loam	SH	48 c	18 d	34 a	Sandy clay loam
	H + DW	62 a	30 b	8 c	Sandy loam
	H + WW	60 b	40 a	0 d	Sandy loam
	H + RW	62 a	26 c	12 b	Sandy loam
Amarillo sandy loam	SH	53 c	17 c	30 a	Sandy clay loam
	H + DW	66 a	22 b	12 b	Sandy loam
	H + WW	63 b	37 a	0 c	Sandy loam
	H + RW	66 a	25 b	9 b	Sandy loam
Dalhart loamy sand	SH	50 b	22 c	28 a	Loam
	H + DW	62 a	35 b	3 b	Sandy loam
	H + WW	60 a	40 a	0 c	Sandy loam
	H + RW	61 a	36 b	3 b	Sandy loam
Dalhart sandy loam	SH	64 c	10 c	26 a	Sandy loam
	H + DW	78 a	10 c	12 b	Sandy loam
	H + WW	75 b	25 a	0 d	Loamy sand
	H + RW	79 a	15 b	6 c	Sandy loam
Dumas sandy clay loam	SH	76 c	9 b	15 a	Sandy loam
	H + DW	90 a	7 c	3 b	Loamy sand
	H + WW	89 b	11 a	0 c	Sand
	H + RW	91 a	8 bc	1 bc	Sand
Sherm clay	SH	46 b	14 d	40 a	Sandy clay
	H + DW	47 a	31 c	22 b	Loam
	H + WW	47 a	53 a	0 d	Silt loam
	H + RW	47 a	42 b	11 c	Loam

<sup>a</sup> Texture as determined by the Bouyoucos (15) method (from Unger, 16).

<sup>b</sup> Methods were: SH -- standard hydrometer; H + DW -- hydrometer with distilled water; H + WW -- hydrometer with well water; and H + RW -- hydrometer with rain water.

<sup>c</sup> Based on determinations in this study.

<sup>d</sup> Column values for a given soil and particle size followed by the same letter or letters are not significantly different at the 0.05 level of probability (Duncan multiple range test).

**Table 3. Water retention, aggregate stability, and crust strength of selected Southern High Plains soils as affected by water quality.**

Soil	Water <sup>a</sup>	Water retention at			Crust strength at		
		-0.033 MPa	-1.5 MPa	Agg. stab. <sup>b</sup>	48 h	96 h	168 h
		---% by weight---		---%---	----- MPa -----		
Pullman cl	Well	20.2	13.6	81.9	0.13* <sup>c</sup>	0.52*	0.34
	Rain	21.2	14.1	83.5	0.12*	0.43*	0.31
Randall c	Well	31.8	22.2	76.5	0.13*	0.53*	0.53*
	Rain	33.2	24.2	72.1	0.11*	0.85*	0.74*
Portales scl	Well	21.9	14.5	78.9	-- <sup>d</sup>	--	--
	Rain	23.6	14.1	82.5	--	--	--
Amarillo scl	Well	15.5	7.0	71.9	0.09*	0.51*	0.41*
	Rain	16.4	6.8	66.6	0.08*	0.59*	0.48*
Amarillo sl	Well	10.9	7.0	49.0	0.11*	0.77	0.64*
	Rain	11.7	6.8	58.5	0.08*	0.75	0.73*
Dalhart sl	Well	10.1	7.9	55.6	0.15*	0.63	0.45
	Rain	11.3	7.7	61.3	0.17*	0.62	0.43
Sherm c	Well	18.4	11.8	75.5	0.12	0.75	0.60
	Rain	19.6	12.4	82.4	0.12	0.75	0.56

<sup>a</sup> Water: Well -- same as used for H + WW treatment; Rain -- same as used for H + RW treatment.

<sup>b</sup> Aggregate stability.

<sup>c</sup> Column values for a given soil and determination followed by an asterisk (\*) are significantly different at the 0.05 level of probability based on the t-test.

<sup>d</sup> Not determined.

significant at the  $P = 0.05$  level, reflect the differences in particle size distribution (micro-aggregation) that resulted from using different waters.

#### Aggregate stability

For a given soil, aggregate stabilities were not different when determined with rain water and well water (Table 3). However, for all soils, except Randall clay and Amarillo sandy clay loam, aggregate stability was numerically greater when determined with rain water than with well water. These results seemingly contradict the particle size distribution and water retention results. Interactions among cations, anions, and minerals in soils and chemicals in water are known to result in different trends in aggregate

stability (6, 12, 13), and undoubtedly influenced results obtained in this study. In addition, the aggregates were wetted under vacuum, which probably minimized effects of water quality on aggregate stability. Under field conditions, wetting occurs due to rainfall, or due to sprinkler, furrow, or flood irrigation. As a result, differences in aggregate stability in the field could be vastly different than those obtained in the laboratory. For example, mean aggregate stability of Pullman surface soil (0- to 7.5-cm depth) for different tillage methods and cropping systems was 69% when wetted under vacuum, but only 12% when wetted in air (14).

#### Crust strength

Although small, some crust strength

differences after 48 h of drying were significant due to the quality of water applied with the rainfall simulator (Table 3). At that time, strength was less with rain water than with well water for four of the six soils. Results were opposite for another soil and identical for the sixth soil. However, at that time, soil surfaces were still moist and crusting would not be of concern with regard to crop seedling emergence.

At 96 h, crust strength was greater with well water than with rain water for Pullman clay loam while the reverse was true for Randall clay and Amarillo sandy clay loam. Differences were not significant for the remaining soils. For Pullman, Randall, and Amarillo soils, crust strengths were inversely related to trends in aggregate stability.

As at 96 h, crust strengths at 168 h were greater with rain water than with well water for Randall clay and Amarillo, sandy clay loam. These trends were inversely related to aggregate stability trends as mentioned above. At 168 h, crust strength was greater with rain water also for Amarillo sandy loam, but the trend was directly related to the trend in aggregate stability. For other soils, crust strength differences at 168 h were not significant. Lower crust strengths at 168 than at 96 h resulted from soil surface cracking in some cases.

The H+WW method of particle size determination resulted in an indicated zero clay content for all soils (Table 2), which indicated that use of well water caused some cohesion among the soil particles. The particle size distribution results suggested that greater cohesion among soil particles would occur also when well water was applied with a rainfall simulator, which, in turn, would result in lower crust strengths than when rain water is applied. Crust strengths were lower with well water than with rain water for Randall clay and Amarillo sandy clay loam at 96 h and for these soils plus Amarillo sandy loam at 168 h. At 96 h, the results were opposite for Pullman clay loam. Differences were not significant for the remaining soils. Lack of greater differences in crust strength due to water quality is attributed to the generally large sand content of all soils, except Pullman clay loam and Randall clay. As a result, simulated rainfall with both types of water resulted in major dispersion of soil

aggregates and, hence, similar crust strengths in most cases. Different results may have been obtained if the rate or amount of water applied had been different. In addition, different results could occur with well water due to different methods of water application, for example, high- or low-pressure sprinkler, flood, or furrow irrigation.

## GENERAL DISCUSSION

The importance of accurately determining soil particle size distribution (true texture) by standard methods is not questioned. However, soils under field conditions are wetted by water from wells or from precipitation. Particle size distributions determined with different types of water indicated major differences in sand, silt, and clay contents in selected soils from the U.S. Southern High Plains. These results indicate that soils under field conditions may behave differently texture-wise than what might be inferred from results of particle size determinations by the standard method. Factors that could be affected include soil aggregate size distribution and stability; crust strength; water infiltration and, hence, runoff and erosion; and possibly soil water retention. Where soils are subjected to different quality waters, it may be advisable to determine the true texture (particle size distribution using the standard method) and the 'natural' texture (particle size distribution with a modified method using the water to which the field soils are subjected). The latter determinations should give results that are more closely related to other soil parameters measured on the field soils.

Although the 'natural' texture of all soils was affected by water quality, soil water retention and aggregate stability were not significantly affected and crust strengths following water application with a rainfall simulator were affected only for some soils. Even so, crust strength results were not consistent. Crust strengths were greater with rain water than with well water for three soils, but the opposite was true for one soil and differences were not significant for the remaining soils. Lack of greater crust strength responses is attributed to the dispersive action of raindrops falling on bare soils, most of which have a

relatively large sand content.

Because of the relatively small or no differences in soil crusting due to the different waters, results of this study indicate the need to provide other means of reducing the potential for crusting on soils that are subject to this problem. One effective means of minimizing crusting is to maintain crop residues on the surface. Surface residues absorb the impact energy of falling raindrops, thus reducing soil aggregate dispersion, particle rearrangement, and surface sealing, all of which affect soil crust formation and soil erosion.

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#### REFERENCES

1. Ahn, P.M. 1974. In Shifting Cultivation and Soil Conservation in Africa. FAO Soils Bull. 24. Food and Agricultural Organization of the United Nations, Rome. pp 123-154.
2. Gee, G.W. & Bauder, J.W. 1986. In A. Klute (ed.) Methods of Soil Analysis, Part 1, Agronomy Monograph 9, 2nd ed. Am. Soc. Agron., Madison, WI, pp 383-411.
3. Agassi, M., Morin, J. & Shainberg, I. 1982. *Geoderma* 28:345-356.
4. Baumhardt, R.L., Wendt, C.W. & Moore, J. 1992. *Soil Sci Soc. Am. J.* 56:261-266.
5. Kazman, Z., Shainberg, I. & Gal, M. 1983. *Soil Sci.* 135:184-192.
6. Shainberg, I., Warrington, D. & Laflen, J.M. 1992. *Soil Sci. Soc. Am. J.* 56:278-283.
7. Shainberg, I. & Singer, M.J. 1988. *Soil Sci. Soc. Am. J.* 52:1449-1452.
8. Smith, H.J.C., Levy, G.J. & Shainberg, I. 1990. *Soil Sci. Soc. Am. J.* 54:1084-1087.
9. Warrington, D., Shainberg, I., Agassi, M. & Morin, J. 1989. *Soil Sci. Soc. Am. J.* 53:1201-1205.
10. Kemper, W.D. 1965. In C.A. Black (ed.-in-chief) Methods of Soil Analysis, Part I, Agronomy Monograph 9. Am. Soc. Agron., Madison, WI, pp 511-519.
11. Merz, D., Spaeth, K. & Shaver, P. 1993. *Tech Note, Range TX-5*. U.S. Dept. of Agric.-Soil Conserv. Serv., Temple, TX.
12. Ali, O.M., Yousaf, M. & Rhoades, J.D. 1987. *Soil Sci. Soc. Am. J.* 51:896-900.
13. Frenkel, H., Goertzen, J.O. & Rhoades, J.D. 1978. *Soil Sci. Soc. Am. J.* 42:32-39.
14. Unger, P.W. 1969. *Misc. Publ. MP-933*. Texas Agric. Exp. Stn., College Station, TX.
15. Bouyoucos, G.J. 1951. *Agron. J.* 43:434-438.
16. Unger, P.W. 1975. *Misc. Publ. MP-1192C*. Texas Agric. Exp. Stn., College Station, TX.