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Soil aggregates as indicator of soil health in waterlogged sodic soil

Sharif Ahamad*[1], S.K. Chaudhari[2], J.C. Dagar[1] and Nirmalendu Basak[1]

[1]*Central Soil Salinity Research Institute, Karnal-132001, Haryana, India*
[2]*Krishi Anusandhan Bhawan-II, ICAR, New Delhi-110012*

ABSTRACT

The aggregates are considered to be indicators of soil health. Soil rich in organic carbon and physical properties have higher water stable aggregates. In present investigation the distribution of water stable aggregates and their indices were compared in waterlogged sodic soil with non-waterlogged soil profiles. Average maximum total water stable aggregates (45.16%) were recorded in 0-15 cm soil depth and they decreased with increased soil depth. In 0-15 cm soil depth, macro aggregates increased from 9.9% in soil with pH 8.5 to 20.3% in soil with pH 9.5 in waterlogged condition and the same decreased to 2.84% on the same soil in non waterlogged condition. However, in soil with pH 8.5 in waterlogged condition, macro aggregates increased to 9.9 and 11.4% in 0-15 cm and 15-30 cm soil depths, respectively. In soil with pH 9.5, however, in waterlogged condition macro aggregates decreased with increasing soil depth.

Key words: soil aggregates, sodic soil, waterlogging, water stable aggregates

Introduction

Soil aggregate is a group of primary soil particles which cohesion within by soil physical, chemical and biological influences. Some of the most important factors influencing the aggregation include surface tension, intermolecular attractive forces between water and solids, precipitated solutes, roots and fungal hyphae and various chemical phenomena. The complex dynamics of aggregation are the result of the interaction of many factors, including the environment, soil management factors, plant influences and soil properties such as mineral composition, texture, soil organic carbon (SOC) concentration, pedogenic processes, microbial activities, exchangeable ions, nutrient reserves, and moisture availability (Kay, 1990). These soil aggregations are the basic index for appraisal of soil physical properties, especially structure, and that are important to sustain soil fertility by reducing soil erosion and mediates air permeability, water infiltration and nutrient cycling (Spohn and Giani, 2011; Zhang *et al.*, 2012). These are the most important agent of retaining soil organic carbon and protect against the decomposition of organic matter (Six *et al.*, 2000). Soil aggregate stability has also been shown to provide a good index of soil erodibility (Kay, 2000; Diaz-Zorita *et al.*, 2002). The soil aggregate stability may be affected by soil texture, organic matter, soil and moisture content (Mostaghimi *et al.*, 1988; Oztas and Fayetorbay, 2003). The abundant water stable aggregates (WSA) in size 0.25-0.1 mm at the upper soil surface layer (0-15 cm) determine the potential for sheet erosion and crust formation (Shouse *et al.*, 1990). For the assessment of physical properties of such soil; and for sustainable crop production and soil health, it is important to examin water stable aggregate (WSA) distribution across the soil profile. Aggregates occur in a variety of manner and size. These are often grouped by size: macro aggregates (>0.25 mm) and micro aggregates (< 0.25 mm) with these groups being further divided by size depending upon soil properties such as binding agents and carbon and nitrogen (N) distribution (Tisdall and Oades, 1982).

To feed ever increasing population more infrastructure such as irrigation facilities, will be required. However, canal irrigation in arid and semi-arid region increased the ground water table over the years followed by waterlogging and secondary soil salinization (SSS). Waterloggong and SSS have affected soil physical properties. Raise in water table is one of major degrading processes of canal command areas in arid and semi-arid regions of world and resultant accumulation of salts in excess for practical and normal production of crops (Ram *et al.*, 2011). These areas mostly exist adjacent to canals especially where drainage facilities are poor, canal levels are higher than ground level and where ground water is of poor quality and is not pumped at rates sufficient to enough to arrest rise in water table due to seepage. Even un-irrigated areas, low lying parts, which act as discharge sites are prone to waterlogging and saline seep problems. Therefore, it is very important to learn how the soil aggregation pattern performed in soil profile under waterlogged conditions. In present investigation an

Table 1. Soil parameters of waterlogged and non-waterlogged micro-plots (mean of 3)

Soil group	Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH		ESP (Initial)	
					Range	Mean	Range	Mean
A	0-15	47.4 ± 0.4	31.3 ± 1.5	21.4 ± 0.7	8.2-8.8	8.6	26.2-34.2	30.2 ± 0.5
	15-30	46.8 ± 0.5	30.7 ± 1.1	22.6 ± 0.5	8.2-8.7	8.6	24.8-35.6	30.2 ± 0.6
	30-45	46.9 ± 0.3	31.5 ± 1.0	22.1 ± 0.8	8.0-8.6	8.4	25.4-34.4	29.9 ± 0.4
	45-60	46.4 ± 1.2	31.2 ± 0.5	22.8 ± 0.9	8.0-8.5	8.4	27.5-35.8	31.7 ± 0.5
	Mean	46.8	31.0	22.2	-	8.5	-	30.5
B	0-15	48.4 ± 0.7	31.0 ± 0.6	22.7 ± 0.5	9.3-9.8	9.7	41.1-61.2	50.7 ± 0.5
	15-30	47.6 ± 0.6	31.1 ± 0.8	21.4± 0.6	9.2-9.7	9.5	42.7-58.2	50.5 ± 0.5
	30-45	47.6 ± 0.8	31.5 ± 0.6	20.9 ± 0.5	9.0-9.4	9.4	37.8-61.0	49.4 ± 0.6
	45-60	46.5 ± 0.8	31.8 ± 0.7	21.8 ± 0.5	9.0-9.3	9.4	40.5-59.3	49.9 ± 0.9
	Mean	47.5	31.3	21.2	-	9.5	-	50.1

attempt have been made to investigate aggregate pattern of waterlogged sodic soil under control conditions.

Material and methods

The present study was carried out at Central Soil Salinity Research Institute, Karnal (latitude 29^{0}43' N, 76^{0}58' E, altitude 245 msl) in Haryana State, India. The climate of the area is subtropical, semiarid, with little or no water surplus megathermic and monsoonal. The actual mean annual rainfall measured at the institute during study period was found to be 800 mm. The maximum rainfall (78%) occurred during July to September. The mean maximum and minimum daily temperatures were 31.3^{0}C and 17.8^{0}C, respectively.

Experimental details

For the assessment of water stable aggregates and their indices two soil conditions were investigated first waterlogged and other non-waterlogged having two pH groups-one pH ranging from 8.2-8.8 (average 8.5) and another from pH 9.3-9.7 (average 9.5); each group having three replications. The initial soil properties are shown in Table 1.

The study was conducted in 12 micro-plots each 6 m x 3 m in size and 90 cm deep constructed by bricks and cement. The soil profile in all the plots was 90 cm deep. Artificially created waterlogging conditions were developed in six micro plots by lining with plastic sheets before filling the soil and installing PVC pipes at bottom of micro-plot connecting with water tank (6m x 0.5m and 0.9m depth) constructed parallel to the micro-plots. The water table was maintained by filling the water tank regularly up to the brim of micro-plot. The water entered to micro-plots by seepage through PVC pipe and came to the surface by capillary action in the soil. The water in reservoir replenished every day that lost through evaporation/ transpiration. Another six micro-plots were maintained as without waterlogging.

After six months of waterlogging intensive soil sampling of micro-plots were done following standard procedure from the soil depth of 0-15, 15-30, 30-45 and 45-60 cm. Soil samples were divided in two parts. First part used for chemical analysis. After grinding, the air dried soil samples were passed through a 2 mm sieve and analyzed for different soil parameters. The mechanical analysis was done by the Pipette method (Piper, 1967). Another part air dried ungrounded samples were passed through 5 mm sieve and were used for estimating aggregate size distribution by wet sieving method (Yoder, 1936) by using a set of sieves having pore diameter 2.0, 1.0, 0.5, 0.25, 0.10 and 0.05 mm for the measurement of total water stable aggregate percentage, macro aggregate percentage, aggregate stability, mean weight diameter and geometry mean diameter. Samples were used for estimating such indices without dispersion and after dispersion with 5% (w/v) sodium hexametaphosphate in 1:3 (soil: solution) ratio by mechanically stirring the suspension for five minutes before the vertical oscillation of the apparatus for 30 minute at the frequency of 50 cycles per minute with taking care that the samples on the top sieve remain immersed throughout the stroke. Before starting the oscillation, soil was left for shaking in water for two minutes. Sieves were then taken out and kept until water was drained out. The water stable aggregates (without dispersion) of different sizes were collected from the respective sieves separately and weighted after oven drying at 50 ^{0}C for 24 h. Water stable macro aggregate and total water stable aggregate: The macro aggregates were determined by adding the aggregates retained over 0.25 – 2.0 mm sieves while the total water stable aggregates referred to adding retained on 0.05 – 2.0 mm sieves using the formula:

WSA (%) = [(weight of soil + sand)*i – (weight of sand)]/ weight of soil sample

where 'i' denotes the size of the sieve. The percentage of water stable macro-aggregates and water stable micro-aggregates is the summation of soil aggregates size fractions of >0.25 mm and <0.25 mm, respectively. These two summed up to estimate the total water stable aggregates.

Mean weight diameter (MWD) and geometry mean diameter (GMD) of aggregates were calculated as:

$$MWD\ (mm) = \Sigma^{n}_{i=1}\ XiWi/\ \Sigma^{n}_{i=1}Wi$$

$$GMD\ (mm) = \exp\ [\Sigma^{n}_{i\text{-}1}Wi\ \log Xi/\ \Sigma^{n}_{i\text{-}1}Wi]$$

where n is the number of fractions (0.1-0.25, 0.25-0.50, 0.50-1.0, 1.0-2.0 and >2.0 mm), Xi is the mean weight diameter (mm) of the sieve size class (0.175, 0.375, 0.75, 1.5 and 2.0 mm) and Wi is the weight of soil (g) retained in each sieve.

The aggregate stability (AS) of soils was computed as:

As = (Percent soil particles >0.25 mm – Percent primary particle >0.25 mm)/ (Percent primary particle <0.25 mm)

The aggregate ratio (AR) of soils was computed as:

AR = [Percent of water stable macro-aggregates]/ [Percent of water stable micro-aggregates]

Statistical analysis

Statistical analysis was performed using SPSS programme to determine the statistical significance of soil condition effect. Duncan's Multiple Range Test (DMRT) was used to compare mean through least significant difference. The 5% probability level is regarded as statistically significant.

Results and discussion

In the present investigation the distribution of soil mass among the size classes of water stable aggregates are strongly influenced (significant at p = 0.05) by the waterlogging condition of soil and soil pH in the soil profile range depth from (0-15, 15-30, 30-45 and 45-60 cm soil depth). The total water stable aggregates and its indices such as AR, MWD, GMD and AS are higher in surface layer than in sub-surface layers (Table 2).

The results showed that total water stable aggregates were found higher (45.16%) in 0-15 cm layer to be 10.31%, 3.49% and 3.37% in lower 15-30, 30-45 and 45-60 cm depth, respectively. Das, *et al*. (2014) also reported that the soil aggregates decreased with increasing the soil depth. Although, the higher total water stable aggregates in surface layer could be cause of contained more organic matter which added by crop residues. Shreyasi *et al*. (2014) expressed in a study that soil aggregation increased by improving of organic matter in soil, which can manage through conservational tillage and residue management, in tropical soils. However, the maximum (64.52%) total water stable aggregates were found in non-waterlogged pH 8.5 soil condition in 45 to 60 cm soil depth followed by (60.12%) in 15-30 cm soil depth (Fig. 1). The contained of water stable aggregates in soil improved the nutrient status especially nitrogen and carbon (Qiang *et al.*, 2007).

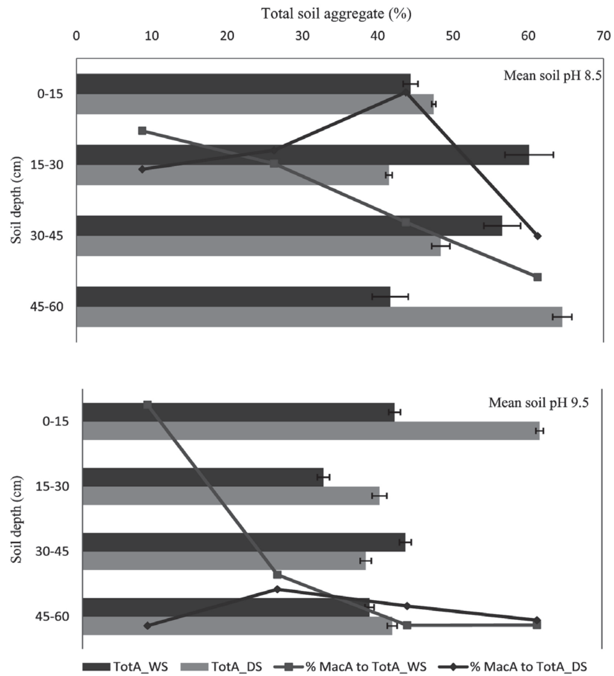

Fig. 1. Soil aggregates in different soil depths at mean pH 8.5 and 9.5 under waterlogged and non- waterlogged conditions.

Depictions: TotA_WS and TotA_DS: Total aggregates under waterlogged and non-waterlogged conditions, respectively; MacA to TotA_WS and MacA to TotA_DS: Ratio of macro-aggregates to total aggregates under waterlogged and non-waterlogged conditions, respectively.

The results showed that the upper layer contain more macro aggregates and decreased as in increased soil depth in the soil profile (Fig. 1). Shreyasi *et al*. (2014) also reported that the macro aggregates decreased with increasing soil depth. The macro aggregates increased from 9.9% at pH 8.5 to 20.3% at pH 9.5 at soil depth 0-15 cm in waterlogged condition. In contrast, in non-waterlogged soil conditions the macro aggregates decreased from 8.7 at pH 8.5 to 2.8% at pH 9.5 at the same soil depth. Under the waterlogged conditions, organic matter decomposition rate was very slow, that might had prevented the decomposition of organic residues, hence hindering in formation of soil aggregation. However, in the waterlogged condition under low pH it helps in improving the soil aggregation. The result showed that the trend of micro aggregates increased with increasing with soil depth (Fig. 1) and the same trend was also reported by Shreyasi *et al*. (2014).

Conclusion

The wide range of total water stable aggregates (27.83-64.52%) were recorded in waterlogged and non-

Table 2. Soil physical indices under waterlogged and non-waterlogged sodic soils

Treatments	Total WSA (%)	Macro A (%)	Micro A (%)	AR	MWD (mm)	GMD (mm)	AS
0-15cm depth							
WL pH 8.5	44.37^{c} ± 0.97	9.92^{b} ± 0.20	34.45^{c} ± 0.81	0.29^{b} ± 0.00	0.34^{b} ± 0.01	0.16^{b} ± 0.02	0.30^{a} ± 0.01
WL pH 9.5	36.05^{d} ± 0.69	20.31^{a} ± 0.41	15.74^{d} ± 0.50	1.29^{a} ± 0.05	0.62^{a} ± 0.01	0.48^{a} ± 0.01	0.31^{a} ± 0.00
NWL pH 8.5	47.44^{b} ± 0.28	8.68^{c} ± 0.28	38.76^{b} ± 0.56	0.22^{b} ± 0.01	0.23^{c} ± 0.00	0.05^{c} ± 0.00	0.29^{a} ± 0.00
NWL pH 9.5	52.80^{a} ± 0.43	2.84^{d} ± 0.26	49.96^{a} ± 0.20	0.06^{c} ± 0.00	0.18^{d} ± 0.01	0.01^{d} ± 0.00	0.26^{b} ± 0.00
Mean	45.16	10.44	34.73	0.47	0.34	0.18	0.29
15 - 30 cm depth							
WL pH 8.5	60.12^{a} ± 3.22	11.36^{a} ± 0.33	48.76^{a} ± 3.06	0.23^{ab} ± 0.01	0.24^{bc} ± 0.01	0.06^{b} ± 0.01	0.25^{d} ± 0.01
WL pH 9.5	27.83^{c} ± 0.70	4.77^{c} ± 0.34	23.05^{c} ± 0.60	0.21^{b} ± 0.02	0.31^{a} ± 0.01	0.10^{a} ± 0.01	0.35^{a} ± 0.00
NWL pH 8.5	41.51^{b} ± 0.43	8.43^{b}± 0.31	33.08^{b} ± 0.56	0.26^{a} ± 0.01	0.25^{b} ± 0.00	0.07^{b} ± 0.00	0.29^{c} ± 0.00
NWL pH 9.5	34.30^{c} ± 0.86	4.73^{c} ±0.08	29.57^{b} ± 0.79	0.16^{c} ±0.00	0.21^{c} ± 0.00	0.02^{c} ± 0.00	0.32^{b} ± 0.00
Mean	40.94	7.32	33.62	0.21	0.25	0.06	0.30
30 - 45 cm depth							
WL pH 8.5	56.54^{a} ± 2.44	7.18^{b} ± 0.27	49.36^{a} ± 2.48	0.15^{b} ± 0.01	0.22^{a} ± 0.01	0.04^{a} ± 0.00	0.26^{b} ± 0.01
WL pH 9.5	37.29^{c} ± 0.69	2.04^{d} ± 0.27	35.25^{b} ± 0.41	0.06^{c} ± 0.01	0.17^{b} ± 0.01	0.01^{b} ± 0.00	0.31^{a} ± 0.00
NWL pH 8.5	48.37^{b} ± 1.21	12.79^{a} ± 0.41	35.59^{b} ± 0.93	0.36^{a} ± 0.01	0.24^{a} ± 0.00	0.05^{a} ± 0.00	0.29^{a} ± 0.00
NWL pH 9.5	32.72^{c} ± 0.64	3.25^{c} ± 0.48	29.47^{c} ± 0.31	0.11^{b} ± 0.02	0.21^{a} ± 0.01	0.02^{b} ± 0.00	0.30^{a} ± 0.01
Mean	43.73	6.31	37.42	0.17	0.21	0.03	0.29
45 - 60 cm depth							
WL pH 8.5	41.67^{b} ± 2.40	2.87^{b} ± 0.17	38.80^{b} ± 2.54	0.08^{b} ± 0.01	0.22^{b} ± 0.00	0.04^{b} ± 0.00	0.31^{ab} ± 0.01
WL pH 9.5	33.15^{c} ± 0.52	1.83^{c} ± 0.06	31.32^{c}± 0.50	0.06^{b} ± 0.00	0.24^{a} ± 0.00	0.06^{a} ± 0.00	0.32^{a} ± 0.00
NWL pH 8.5	64.52^{a} ± 1.27	7.25^{a} ± 0.33	57.27^{a} ± 1.20	0.13^{a} ± 0.01	0.19^{c} ± 0.00	0.02^{d} ± 0.00	0.20^{c} ± 0.00
NWL pH 9.5	35.77^{c} ± 0.56	2.37^{c} ±0.05	33.40^{c} ± 0.60	0.07^{b} ± 0.00	0.21^{b} ± 0.00	0.03^{c} ± 0.00	0.29^{b} ± 0.01
Mean	43.78	3.58	40.20	0.08	0.22	0.04	0.28

Same superscripted letters in a column show that the data are non-significant in a particular soil depth.
Depictions WL- waterlogged, NWL- non-waterlogged

waterlogged conditions, which were affected due to variation in pH of soils. Average total water stable aggregates and their indices were recorded higher in 0-15 cm soil layer and decreased with increase in soil depth. Average macro aggregates were also decreased with increase soil depth, however, in soil with pH 8.5 in waterlogged condition, macro aggregates increased to 9.9 and 11.4% in 0-15 cm and 15-30 cm soil depths, respectively.

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