



## SOIL STRUCTURE AND ORGANIC CARBON STABILITY OF RAINFED ALFISOLS UNDER LONG-TERM APPLICATION OF MANURE AND FERTILIZERS

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### ABSTRACT

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An experiment on long-term application of fertilizers and manure was initiated in the year 1981 during *kharif* season at Regional Agricultural Research Station, Tirupati, Andhra Pradesh, India in rainfed *Alfisols* under groundnut monocropping system. The same experiment was used for the present investigation during *kharif*, 2021 season, to study the influence of long-term application of fertilizers and manure on soil aggregate and aggregate associated carbon. The experiment has eleven treatments each replicated four times in a randomized block design. The results revealed that the soil aggregate fractions under long-term application of FYM @ 5 t ha<sup>-1</sup> (T<sub>2</sub>) and treatment combinations viz., NPK+gypsum+ZnSO<sub>4</sub> (T<sub>11</sub>), NPK + lime (T<sub>10</sub>), NPK + gypsum (T<sub>9</sub>) and NPK (T<sub>8</sub>) recorded significantly higher in large and small macro-aggregates fractions compared to control and single nutrient fertilizers, which recorded highest in micro-aggregates fractions. The aggregate associated-C recorded significantly higher in large macro-aggregates compared to small macro and micro-aggregate fractions in both the soil layers. However, the aggregate associated-C was higher in surface layer compared to sub-surface layer.

**KEYWORDS:** Aggregates, *Alfisols*, long-term, treatment combinations.

### INTRODUCTION

Long-term fertilizer experiments plays an important role in understanding the changes in physical and physico-chemical properties and productivity of the crops. The decline in soil fertility due to the imbalanced fertilizer use has been recognized as one of the most important factors limiting crop yield (Nambiar and Abrol, 1989). This LTFE also provides valuable information on impact of continuous use of fertilizers with varying combination of organics and inorganics on soil physical and chemical properties and became good platform for monitoring the changes. Inorganic and organic fertilizers are the important factors for maintenance and improvement of soil fertility and aggregation. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues. Addition of SOM enhances soil organic carbon (SOC) content, which is an important indicator of soil quality and crop productivity. The combined application of inorganic fertilizers and organic manures could affect the soil physical properties such as soil aggregation, aggregate stability, water holding capacity, porosity,

infiltration rate, hydraulic conductivity and bulk density directly or indirectly due to increased SOC content.

Sustaining the soil quality is the most appropriate method to ensure sufficient in food production in any agro-ecosystem. Hence, the maintenance of soil organic carbon pool is considered essential for long-term sustainable productivity. Soil organic matter being a store house of all essential plant nutrients, it plays a pivotal role in crop production. The soil organic carbon together with physical properties has been proposed as indicator of soil quality (Doran and Parkin, 1994). The important indicators of soil quality in relation to soil organic carbon content are mean weight diameter (MWD) of aggregates, available water holding capacity, cation exchange capacity (CEC) and bulk density (BD). The relative importance of these indicators varies among different soils and therefore, site-specific information is needed on these properties for quantitative assessment of soil quality (Lai *et al.* 1998). In view of the utmost significance of soil organic carbon in determining soil quality, adoption of judicious management practices to restore and upgrade soil organic carbon pool is essential

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## MATERIAL AND METHODS

### Study area and climate

The present study was carried out as part of the long-term experiment during *kharif*, 2021 on red sandy loam (*Haplustalf*) soils at Regional Agricultural Research Station, Acharya N.G Ranga Agricultural University, Tirupati, Chittoor district, Andhra Pradesh. The experiment was laid out in randomized block design with eleven treatments and four replications. The treatments includes T<sub>1</sub> : control (no manure and fertilizers), T<sub>2</sub> : Farm yard manure @ 5 t ha<sup>-1</sup> (once in 3 years), T<sub>3</sub> : 20 kg nitrogen (N) ha<sup>-1</sup>, T<sub>4</sub> : 10 kg phosphorus (P) ha<sup>-1</sup>, T<sub>5</sub> : 25 kg potassium (K) ha<sup>-1</sup>, T<sub>6</sub> : 250 kg gypsum ha<sup>-1</sup>, T<sub>7</sub> : 20 kg N + 10 kg P ha<sup>-1</sup>, T<sub>8</sub> : 20 kg N + 10 kg P + 25 kg K ha<sup>-1</sup>, T<sub>9</sub> : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum ha<sup>-1</sup>, T<sub>10</sub> : 20 kg N + 10 kg P + 25 kg K + 100 kg lime ha<sup>-1</sup>, T<sub>11</sub> : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum + 25 kg ha<sup>-1</sup> zinc sulphate (once in 3 years). The nutrients NPK were applied through the fertilizers like urea, single super phosphate and muriate of potash. The farmyard manure and ZnSO<sub>4</sub> were not applied in this *kharif* season. The test crop was groundnut and variety selected was Dharani. The crop was sown on 09-07-2021 and harvested on 23-10-2021. The weekly mean maximum temperature during the crop period ranged from 31.6 to 35.6°C with an average of 33.5°C while the weekly mean minimum temperature ranged between 22.6 to 25.7°C with an average of 24.5°C. The weekly mean relative humidity ranged between 57.4 to 79.1 per cent with an average of 68.8 per cent. The weekly mean sunshine hours during the crop period ranged between 1.9 to 8.0 h day<sup>-1</sup> with an average of 4.71 h day<sup>-1</sup>. The weekly mean evaporation ranged between 2.7 to 4.8 mm day<sup>-1</sup> with an average of 3.8 mm day<sup>-1</sup>. A total rainfall of 764.6 mm was received in 42 rainy days during the crop growth period.

### Soil sampling and laboratory analysis

Soil samples were collected from 0-15 and 15-30 cm depth after harvest of the crop. While collecting the samples two pits were dug in each plot with the help of spade. The two soil samples were mixed separately depth wise, dried under shade and labelled. The soil samples so collected were analyzed for physical and physico-chemical properties by using standard procedures. Aggregate analysis was done by wet sieving method

(Yoder, 1936) for two depths *i.e.* 0–15 cm and 15–30 cm. The Yoder apparatus have a vertical stroke of 45 mm, and was operated for 10 min at a speed of 28 to 32 strokes per min. A bunch of sieves comprising of six sieves of various breadths going from 5 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm secured to a holder, through a distance of 3.18 cm arranged in assembly at a descending order. The soil sample (5 to 8 mm size) was kept on the top of 5 mm sieve and allowed to wet in water for 10 min. The sieves were then swayed vertically and rhythmically, so that water was made to flow up and down throughout the screens and the assemblage of aggregates. At the end of 10 minutes period, the nest of sieves was removed carefully from the water, and aggregates retained on the each sieve was back washed into a pre-weighed beakers and dried in oven at 105 °C for 24 hrs. After drying, weight of aggregate retained on each sieve was weighed.

The organic carbon content of the soil aggregates were estimated by the method given by Walkley and Black wet oxidation (1934) as outlined by Jackson (1973) and was expressed in percentage.

## RESULTS AND DISCUSSION

### Soil aggregation

Soil aggregate fractions under long-term application of FYM @ 5 t ha<sup>-1</sup> (T<sub>2</sub>) and treatmental combinations *viz.*, NPK + gypsum + ZnSO<sub>4</sub> (T<sub>11</sub>), NPK + lime (T<sub>10</sub>) and NPK + gypsum (T<sub>9</sub>) recorded significantly higher in large and small macro-aggregates fractions compared to control and single nutrient fertilizers, which recorded highest in micro-aggregates fractions. In surface layer (0-15 cm), the micro-aggregates (<0.25 mm) ranged from 19.93 to 31.03 per cent with the mean of 24.92 per cent. The highest was observed in control (T<sub>1</sub>) (31.03%) and which was on par with the treatment P alone (T<sub>4</sub>) (27.97%), N alone treated plot (T<sub>3</sub>) (27.80%) and NPK treated plot (T<sub>8</sub>) (26.97%). Whereas, the lowest was observed in FYM alone treated plot (T<sub>2</sub>) (19.93%). The small macro-aggregates (2-0.25 mm) ranged from 55.73 to 62.77 per cent with the mean of 59.01 per cent. The highest was observed in NPK + gypsum (T<sub>9</sub>) (62.77%) and which was on par with FYM alone (T<sub>2</sub>) (62.27%), NP (T<sub>7</sub>) (61.60%) and NPK + lime (T<sub>10</sub>) (60.23%). Whereas, the lowest was observed in NPK + gypsum + ZnSO<sub>4</sub> (T<sub>11</sub>) (55.73%). The large macro-aggregates (>2

**Table 1. Effect of long-term application of manure and fertilizer on soil aggregate proportion mass in aggregate class (%) at surface and sub-surface layers after harvest**

Treatments	Micro-aggregate (< 0.25 mm)		Small macro-aggregate (2-0.25 mm)		Large macro-aggregate (> 2 mm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T <sub>1</sub> : Control	31.03	25.20	56.13	58.03	12.83	16.77
T <sub>2</sub> : FYM @ 5 t ha <sup>-1</sup> (once in 3 years)	19.93	20.00	62.27	59.67	17.80	20.33
T <sub>3</sub> : N @ 20 kg ha <sup>-1</sup>	27.80	22.80	57.47	59.60	14.73	17.60
T <sub>4</sub> : P @ 10 kg ha <sup>-1</sup>	27.97	25.30	57.43	55.03	14.60	19.67
T <sub>5</sub> : K @ 25 kg ha <sup>-1</sup>	25.03	25.73	60.03	57.30	14.93	16.97
T <sub>6</sub> : Gypsum @ 250 kg ha <sup>-1</sup>	25.03	26.07	59.17	54.77	15.80	19.17
T <sub>7</sub> : NP	22.40	22.53	61.60	58.30	16.00	19.17
T <sub>8</sub> : NPK	26.97	28.13	56.30	52.83	16.73	19.03
T <sub>9</sub> : NPK + gypsum	20.63	20.50	62.77	59.97	16.60	19.53
T <sub>10</sub> : NPK + lime @ 100 kg ha <sup>-1</sup>	22.17	22.63	60.23	56.87	17.60	20.50
T <sub>11</sub> : NPK + gypsum + ZnSO <sub>4</sub> @ 25 kg ha <sup>-1</sup>	25.17	21.80	55.73	57.80	19.10	20.40
<b>Mean</b>	<b>24.92</b>	<b>23.70</b>	<b>59.01</b>	<b>57.28</b>	<b>16.07</b>	<b>19.01</b>
<b>SEm±</b>	<b>1.77</b>	<b>1.26</b>	<b>1.51</b>	<b>1.37</b>	<b>1.07</b>	<b>0.91</b>
<b>CD (P=0.05)</b>	<b>5.25</b>	<b>3.73</b>	<b>4.47</b>	<b>4.06</b>	<b>3.17</b>	<b>NS</b>

mm) ranged from 12.83 to 19.10 per cent with the mean of 16.07 per cent. The highest was observed in NPK + gypsum + ZnSO<sub>4</sub> (T<sub>11</sub>) (19.10%) and which was on par with FYM alone (T<sub>2</sub>) (17.80%), NPK + lime (T<sub>10</sub>) (17.60%) and NPK (T<sub>8</sub>) (16.73), whereas lowest was observed in control (T<sub>1</sub>) (12.83%).

In sub-surface layer (15-30 cm), the micro-aggregates (<0.25 mm) ranged from 20.00 to 28.13 per cent with the mean of 23.70 per cent. The highest was observed in NPK (T<sub>8</sub>) (28.13 %) and which was on par with gypsum (T<sub>6</sub>) (26.07%), K (T<sub>5</sub>) (25.73%) and P treated plots (T<sub>4</sub>) (25.30%), whereas lowest was observed in FYM alone treated plot (T<sub>2</sub>) (20.00%). The small macro-aggregates (2-0.25 mm) ranged from 52.83 to 59.97 per cent with the mean of 57.28 per cent. The highest was observed in NPK + gypsum treatment (T<sub>9</sub>) (59.97%) and which was on par with FYM alone (T<sub>2</sub>) (59.67%), N alone (T<sub>3</sub>) (59.60%) and NP (T<sub>7</sub>) (58.30%) treated plots, whereas lowest was observed in NPK (T<sub>8</sub>) (52.83%) treatment. The large macro-aggregates (>2 mm) ranged from 16.77 to 20.50 per cent with the mean of 19.01 per cent. The highest was observed in NPK + lime (T<sub>10</sub>) (20.50%) followed by NPK + gypsum + ZnSO<sub>4</sub> (T<sub>11</sub>) (20.40%) and FYM (T<sub>2</sub>) (20.33%), treated plots whereas lowest was observed in control (T<sub>1</sub>) (16.77%).

The results revealed that, among the soil aggregate fractions (%) small macro-aggregates are higher compared to large macro and micro-aggregates in both surface and sub-surface layers. The data revealed that aggregate fraction of size >0.25 mm were in higher in treatments received with FYM alone, NPK + lime, NPK + gypsum and NPK+gypsum+ZnSO<sub>4</sub> treatments compared to other treatments. This might be due to the increased root biomass which indirectly helped in improvement of large and small macro-aggregates stabilization in aforesaid treatments. Whereas the aggregate fraction of <0.25 mm size was significantly higher in treatment received with only inorganic fertilizers and control treatments compared to the other treatments. Interestingly, microaggregates fraction was decreased with the application of FYM alone in both surface and sub-surface soils. This indicates that higher formation of larger aggregates with the supplementation of organic matter. The present results are in agreement with the findings of Chakraborty *et al.* (2010) who reported that organic manure incorporation increased soil macro-aggregate proportion. The higher percentage of

aggregates <0.25 mm was evidenced under single nutrient treatments *viz.*, N, P, K and control in surface and sub-surface layers, which might be ascribed to comparatively low level of carbonates and organic matter. These results are in agreement with the findings of Manna *et al.* (2007) and Ghosh *et al.* (2010). The lower percentage of large macro-aggregates (>2 mm) in control plot in surface (12.83%) and sub-surface (16.77%) layers, respectively, might be due to comparatively lesser binding materials compared to other treatments. Similar findings were reported by Aziz and Karim (2016).

### Aggregate association carbon

In surface layer (0-15 cm), the aggregate associated-C in micro-aggregates (<0.25 mm) ranged from 2.47 to 4.18 g kg<sup>-1</sup> with the mean of 3.06 g kg<sup>-1</sup>. The highest was observed in gypsum alone treated plot (T<sub>6</sub>) (4.18 g kg<sup>-1</sup>) and the lowest was observed in NP (T<sub>7</sub>) (2.47 g kg<sup>-1</sup>) treatment. The aggregate associated-C in small macro-aggregates (2-0.25 mm) ranged from 2.80 to 3.95 g kg<sup>-1</sup> with the mean of 3.22 g kg<sup>-1</sup>. The highest was observed in FYM alone (T<sub>2</sub>) (3.95 g kg<sup>-1</sup>) and lowest was observed in NP (T<sub>7</sub>) (2.80 g kg<sup>-1</sup>) treated plots. And the aggregate associated-C in large macro-aggregates (>2 mm) ranged from 3.36 to 5.01 g kg<sup>-1</sup> with the mean of 4.10 g kg<sup>-1</sup>. The highest was observed in FYM alone treated plot (T<sub>2</sub>) (5.01 g kg<sup>-1</sup>) and lowest was observed in control (T<sub>1</sub>) (2.80 g kg<sup>-1</sup>). In sub-surface layer (15-30 cm), the aggregate associated-C in micro-aggregates (<0.25 mm) ranged from 2.42 to 3.48 g kg<sup>-1</sup> with the mean of 3.01 g kg<sup>-1</sup>. The highest was observed in FYM alone (T<sub>2</sub>) (3.48 g kg<sup>-1</sup>) and lowest was observed in NP (T<sub>7</sub>) (2.42 g kg<sup>-1</sup>) treatments. The aggregate associated-C in small macro-aggregates (2-0.25 mm) ranged from 2.68 to 3.58 g kg<sup>-1</sup> with the mean of 3.05 g kg<sup>-1</sup>. The highest was observed in FYM alone treatment (T<sub>2</sub>) (3.58 g kg<sup>-1</sup>) and lowest was observed in control (T<sub>1</sub>) (2.68 g kg<sup>-1</sup>). And the aggregate associated-C in large macro-aggregates (>2 mm) ranged from 3.02 to 4.12 g kg<sup>-1</sup> with the mean of 3.41 g kg<sup>-1</sup>. The highest was observed in FYM alone treatment (T<sub>2</sub>) (4.12 g kg<sup>-1</sup>) and lowest was observed in control (T<sub>1</sub>) (3.02 g kg<sup>-1</sup>).

The results indicated that SOC was significantly higher in large macro-aggregates when compared to small macro and micro-aggregates. The higher SOC within large macro-aggregates might be due to carbon associated with the formation of microaggregates inside

Table 2. Effect of long-term application of manure and fertilizers on aggregate associated-C ( $\text{g kg}^{-1}$ ) at surface and sub-surface layers after harvest

Treatments	Micro-aggregate ( $< 0.25$ mm)			Small macro-aggregate ( $2-0.25$ mm)			Large macro-aggregate ( $> 2$ mm)		
	0-15 cm	15-30 cm	0-15 cm	0-15 cm	15-30 cm	0-15 cm	0-15 cm	15-30 cm	
	T <sub>1</sub> : Control	2.87	2.98	2.86	2.68	2.68	3.36	3.02	3.02
T <sub>2</sub> : FYM @ 5 t ha <sup>-1</sup> (once in 3 years)	2.77	3.48	3.95	3.58	3.58	5.01	4.12	4.12	
T <sub>3</sub> : N @ 20 kg ha <sup>-1</sup>	2.70	2.72	2.91	2.83	2.83	3.69	3.24	3.24	
T <sub>4</sub> : P @ 10 kg ha <sup>-1</sup>	3.10	2.51	2.91	3.04	3.04	3.54	3.53	3.53	
T <sub>5</sub> : K @ 25 kg ha <sup>-1</sup>	3.23	3.28	2.87	2.86	2.86	3.91	3.22	3.22	
T <sub>6</sub> : Gypsum @ 250 kg ha <sup>-1</sup>	4.18	3.05	3.61	3.33	3.33	4.17	3.65	3.65	
T <sub>7</sub> : NP	2.47	2.42	2.80	2.82	2.82	3.70	3.04	3.04	
T <sub>8</sub> : NPK	2.60	3.33	3.81	3.28	3.28	4.45	3.69	3.69	
T <sub>9</sub> : NPK + gypsum	3.25	3.15	3.03	2.80	2.80	4.52	3.21	3.21	
T <sub>10</sub> : NPK + lime @ 100 kg ha <sup>-1</sup>	3.37	3.10	3.27	3.08	3.08	4.67	3.47	3.47	
T <sub>11</sub> : NPK + gypsum + ZnSO <sub>4</sub> @ 25 kg ha <sup>-1</sup>	3.17	2.98	3.10	3.27	3.27	4.04	3.32	3.32	
<b>Mean</b>	<b>3.06</b>	<b>3.01</b>	<b>3.22</b>	<b>3.05</b>	<b>3.05</b>	<b>4.10</b>	<b>3.41</b>	<b>3.41</b>	
<b>SEm±</b>	<b>0.18</b>	<b>0.22</b>	<b>0.11</b>	<b>0.08</b>	<b>0.08</b>	<b>0.15</b>	<b>0.14</b>	<b>0.14</b>	
<b>CD (P=0.05)</b>	<b>0.53</b>	<b>0.66</b>	<b>0.33</b>	<b>0.24</b>	<b>0.24</b>	<b>0.45</b>	<b>0.42</b>	<b>0.42</b>	

macroaggregates, which better protects SOC from being lost due to various soil physico-chemical properties. Even though microaggregate associated C concentration is low, it is important for protection of total SOC in soils having lower turnover rates. These results are in conformity with the findings of Yu *et al.* (2012) and Liang *et al.* (2012) who recorded that aggregate formation was associated with increased carbon storage in aggregate fractions >53  $\mu\text{m}$  than in the silt and clay fraction (<53  $\mu\text{m}$ ). The highest aggregate associated-C was found in the case of FYM alone treated plot compared to other treatments, which might be due to FYM application provides different organic carbon compounds to soil directly and increased root biomass and returning large amounts of carbon to the soil indirectly. The lowest aggregate association-C was observed in single nutrient treatments like N, P, K and control in surface and sub-surface layers, might be due to less addition of organic matter thereby reduction in C accumulation in all aggregates fractions. The present results are in agreement with the findings of Zou *et al.* (2018) and Mohan *et al.* (2020). The aggregate associated-C content was decreased with decrease in aggregate size fractions. The results are similar to those of Li *et al.* (2020) who reported that the SOC content was decreased in <0.25 mm aggregates when compared to >0.25 mm aggregate sizes in 9 years long-term experiment. However, long-term amendment of manure significantly increased SOC in macro-aggregates. Similar results were also reported by Zhang *et al.* (2021) and Niu *et al.* (2022).

In conclusion, the present study indicated that long-term application of FYM @ 5 t ha<sup>-1</sup> once in three years was very effective in increasing the soil physical, physio-chemical environment and increase in macro-aggregate fractions. The aggregate associated-C recorded significantly higher in large macro-aggregates compared to small macro and micro-aggregate fractions in both the soil layers. However, the aggregate associated-C was higher in surface layer compared to sub-surface layer. The study also revealed that balanced nutrition treatments *viz.*, NPK + gypsum + ZnSO<sub>4</sub>, NPK + lime, NPK + gypsum and NPK were also equally effective in increasing macro-aggregate fractions. However, long-term application of FYM @ 5 t ha<sup>-1</sup> or NPK + lime improved the soil structure, aggregate and organic carbon stability of rainfed *alfisols*. Whereas the long-term application of K fertilizers alone deteriorated the soil structure and organic carbon stability.

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