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Effect of long-term application of organic and inorganics by using soil test crop response on soil aggregate fractions in western Rajasthan

Suresh Kumawat, SK Kharia, SR Yadav and RK Jakhar

Abstract
A field experiment was started in 2008 under All India Co-ordinated Research Project to study the ‘‘Effect of Long-Term Application of Organic and Inorganics by using Soil Test Crop Response on Soil Aggregate Fractions in Western Rajasthan’’. By using General recommended dose, Target yield 15 q ha^{-1}, Target yield 15 q ha^{-1} with IPNS, Target yield 20 q ha^{-1} and Target yield 20 q ha^{-1} with IPNS. Studying the dynamics of soil organic carbon (SOC) is important for understanding the carbon stabilization into different pools. Thus, a 9-year old experiment was used to assess the impact of soil test crop response system with addition of organics and grades of fertilization on oxidizable carbon and aggregate fractions in western Rajasthan of India. The water stable aggregates in the experimental trail soils ranged from 3.88 to 7.96% under different treatments. Geometric mean diameter also exhibited ranged from 0.725 to 0.795 mm in 0-7.5 cm soil depth to 7.5-15 cm soil depth. Aggregate ratio (AR) showed, with the highest values in soils under IPNS treatment (0.112 and 0.090 in 0-7.5 cm soil depth and 7.5-15 cm soil depth).

Keywords: Soil aggregates, MWD, GMD, Aggregate ratio

Introduction
Analyses of structure of soil are generally done using aggregate distribution methods, which are based on the presume that the alliance of the soil particles and their specific arrangement play a key bit part in the function of soil organic matter (Gregorich *et al.*, 2006) [12]. Soil aggregation plays an important role in maintaining soil structure and sustaining soil fertility. Soil aggregation not only reflects the integrative effects of soil type, environment, plant species, and soil management practices, but also exerts great impacts on many soil processes, such as soil erosion, organic matter protection and available nutrients supply (Martens and Frankenberger 1992; Nyamangara *et al*. 1999; Martens 2000; Madari *et al*. 2005) [24, 27, 23, 22]. Macroaggregates generally have more organic matter and higher nutrient levels than microaggregates, are less susceptible to erosion, and create larger pores for better water infiltration and aeration (Elliott 1986; Niewczas and Witkowska-Walczak 2003; Six *et al*. 2004) [8, 26, 35]. The impacts of cultivation on C stock have commonly been observed to be restricted mostly to surface soils and/or to root zone depth (Paustian *et al.*, 1997) [28]. Addition of SOM enhancessoil organic carbon (SOC) content, which is an important indicator of soil quality and crop productivity (Lal., 2003) [21]. Sequestration of SOC is key to reduce greenhouse gas emissions and lower the carbon footprint of farming (Jarecki and Lal, 2003) [18]. The SOM components such as humic molecules and polysaccharides increased aggregate stability by binding mineral particles into aggregates and reduced their susceptibility to erosion by wind or water (Tisdall and Oades, 1982) [38]. In turn, formation of stable aggregates enhances physical protection of SOM against microbial decomposition (Six *et al*., 1998) [37]. Fertilizer additions also affect the chemical composition of soil solution which can be responsible for dispersion/flocculation of clay particles and thus, affects the soil aggregation stability (Haynes and Naidu, 1998) [17]. Beneficial effects of increasing SOM concentration on enhancing soil structural stability have been widely documented (Tisdall, and Oades, 1982, Barzegar, 1997, and Dexter,1988) [38, 3, 6]. A traditional agricultural practice of applying nutrients was through organic manures such as green manures, farmyard manure (FYM). Organic manure applications improved soil physical properties through increased soil aggregation (Hati *et al*., 2007, Shukla *et al*. 2003, Zhang and Fang,2007) [16, 32, 40] improved aggregate stability (Duiker and Lal, 1999 Barzegar *et al*., 2002, Rachman *et al*. 2003, McVay *et al*., 2006, Pernes-Debuyser, and Tessier, 2004) [7, 3, 30, 25, 29].

The allocation of soil organic carbon (SOC) in different aggregate size group (i.e. micro aggregates, mesoaggregates and macro aggregates) may cause soil erosion more in macroaggregates than microaggregates (Eynard *et al.,* 2005) [10]. Tillage change large aggregates more than smaller aggregates, making SOC more vulnerable to mineralization (Six *et al.,* 1998) [37]. Particles less than 0.002 mm have a higher protective effect on chemical composition and biological processes of carbon maintenance (Christensen, 1996) [5]. Particle have size more than clay and below silt serves as a fixed capacity level (Hassink and Whitmore, 1997) [15] while the combination of micro-aggregate, meso-aggregated, and macro aggregated carbon provide an extra variable capacity. The former is specially soil while depend on soil type and amount of carbon. Cultivated soils have a smaller water stable aggregate within >2 mm and 1-2 mm aggregate size but a greater aggregation in below 0.25 mm size fraction. Tillage may enhance the susceptible to aggregates to disruption by wet-dry cycles that showed to a loss of carbon rich macro aggregate fractions. The mean weight diameter and GMD have lower values in the crops cultivated than the uncultivated soils showing more change through tillage and lower accumulation as well as protection of soil organic carbon in macro-aggregates (Gupta Choudhury *et al.,* 2010) [13].

The smaller aggregates in the crop cultivated land soils are therefore consistent with the low soil organic matter content (Emadi *et al.,* 2008) [9]. Loss of the bigger aggregate sizes in crop cultivated land could by the tillage rapidly breakdown live and rotten plant roots, micro and macro fauna. These factors tend to help the build of larger sized aggregates (Tisdale and Oades 1982) [38]. The loss of big sized WSA (water stable aggregates) under cultivation was also associated with a considerable reduction in stability as determine by the mean weight diameter

Therefore, the experiments showing the beneficial effects of organic matter on aggregate stability have been varied and knowledge of aggregate stability is useful in the evaluation of soil properties with regard to organic amendments. The water stable aggregation helps to measure the soils susceptibility to erosion, compaction and other disruptive forces. Raindrop impact and surface flow of water are primary sources of energy causing disintegration of soil aggregates in the field and thus the attendant soil erosion. Particle size fractions provide a rough differentiation between young (active) and older (intermediate and passive) SOM pools. Our hypothesis was that the changes in soil aggregate stability over time depend on the biochemical nature of the added organic inputs.

Materials and Methods

Experimental design

The experiment was laid out in a Randomized Block Design with five treatment combinations and four replications, and randomization done with the help of a random number table as advocated by (Fisher and Yates 1963) [11].

Study site

The experiment was conducted at the farm of Agricultural Research Station, SKRAU, Bikaner. It is situated in the state of Rajasthan and study area is located in Agroclimatic zone Ic (Hyper arid partially irrigated western plain) of Rajasthan comprising canal irrigated North-Western plains of Bikaner. The climate represent hyper arid with annual rainfall of 247 mm and most (70-80%) of which occurs during July-September.

Description of treatment application

A. Organic manures: Treatments with IPNS, nutrient applied as per the STCR recommendation Kg compost plot^{-1}. Chemical composition of compost was nitrogen (0.68%), phosphorus (0.35%) and potassium (0.62%)

B. Fertilizer application

Application of the fertilizers urea as nitrogen source, single super phosphate for phosphorus and muriate of potash for potassium in without IPNS and under the treatment According to the STCR recommendation, different treatment required different nutrient requirement. These requirement were calculated following equation

For Nitrogen (T_2 and T_4) = 6.70 T* - 0.37 N**

For Nitrogen (T_3 and T_5) = 6.70 T* - 0.37 N** – 0.65 O***N

For Phosphorus (T_2 and T_4) = 9.90 T* - 2.15 $P_2O_5^{**}$

For Phosphorus (T_3 and T_5) = 9.90 T* - 2.15 P_2O_5 **–2.05 X 50 O*** P_2O_5

For potassium (T_2 and T_4) = 6.78 T* – 0.23 K_2O^{**}

For potassium (T_3 and T_5) = 6.78 T* – 0.23 K_2O^{**} – 0.62 O*** K_2O

*target yield ** amount of available nutrient present in soil ***Nutrient per cent in compost

Details of treatments with their symbols

Treatment symbols		Treatment details
T_1-General recommended dose	:	General recommended dose (20 Kg Nitrogen ha^{-1}32 Kg P_2O_5ha^{-1})
T_2-Target yield 15 q ha^{-1}	:	Soil test crop response recommendation dose for target 15 q ha^{-1}
T_3-Target yield 15 q ha^{-1} with IPNS	:	Soil test crop response recommendation under integrated plant nutrient system dose for target 15 q ha^{-1}
T_4-Target yield 20 q ha^{-1}	:	Soil test crop response recommendation dose for target 20 q ha^{-1}
T_5-Target yield 20 q ha^{-1} with IPNS	:	Soil test crop response recommendation under integrated plant nutrient system dose for target 20 q ha^{-1}

Size distribution of Aggregates

Soil samples (0-7.5 cm and 7.5-15 cm soil depths) were collected for determination of different aggregate size. Aggregate status of soil was determined by wet sieving method (Yoder 1936). The soil sample was passed through 8-mm sieve and were retained on 4-mm sieve. Yoder's wet sieving apparatus, comprising of two sieve sets, each having nest of 5 sieves of 12.7 cm diameter and 5 cm height and with hole sizes of 2.0, 0.5, 0.25 and 0.1 mm (with mesh numbers of 8, 16, 32, 64 and 150 respectively), were used for this purpose. The samples were evenly distributed over the top sieve of the set and pre-wetted by capillarity for 10 minutes. The nest of sieves was then allowed to move up and down for 30 minutes. Following this, the sieves were drawn out of water and the oven-dried weight of aggregates retained on each sieve was recorded after drying these in an oven at 105 °C till the constant weight achieved. The data was analyzed to compute mean weigh diameter (MWD) (Youker and McGuinness 1956) [39] and water stable aggregates (WSA) of different size (Kemper and Rosenau 1986) [20]. The MWD, WSA, GMD and Aggregate ratio were calculated using the formula as follows:

$$\text{Mean Weight Diameter} = \sum_{i=1}^{n} DiXWi$$

$$\text{Water Stable Aggregates} > 0.25\ mm\ (\%) = \frac{\sum_{i=1}^{n} DiXWi}{\text{Weight of sample}} X100$$

$$\text{Geometric Mean Diameter (mm)} = \frac{\sum_{i=1}^{n} Wi\ logDi}{\text{Weight of sample}} X100$$

$$\text{Aggregate ratio} = \frac{(\text{Aggregates retained in} > 0.25mm)}{(\text{Aggregates retained in} < 0.25mm)}$$

Where, nis number of size fractions (the finest fraction that passes through the finest sieve inclusive), D_i is the mean diameter of each size range, W_i is the weight of aggregates in that size range as a fraction of the total dry weight of the sample analyzed.

Statistical analysis
By using SPSS (Statistical Package for the Social Science), software developed by three PhD students at the University of Stanford (Norman H. Nie, C. Hadlai (Tex) Hull and Dale H. Bent), after graduation N.

Results and Discussion

Effect of organic and inorganic on coarse macro-, coarsemeso-, coarse meso- and micro size aggregate in 0-7.5 cm soil depth
In the table 2 indicate the coarse macro size aggregate, coarse meso size aggregate, coarse meso size aggregate and micro size aggregate in per cent. Highest mean value of coarse macro size aggregate and coarse meso size aggregate were found in treatment T_5 (*i.e.*Target yield 20 q ha^{-1}) with IPNS and lowest mean value of coarse macro size aggregate, coarse meso size aggregate were found in treatment T_4 (*i.e.*Target yield 20 q ha^{-1}).Highest mean value of coarse meso size aggregate was found under the treatment under treatment T_3(*i.e.*Target yield 15 q ha^{-1} with IPNS) and lowest mean value was found under the treatment T_1 (*i.e.*General recommended dose).The highest mean value of micro size aggregate was found under the treatment T_4(Target yield 20 q ha^{-1}) and lowest value of micro size aggregate was found under the treatment T_5(Target yield 20 q ha^{-1} with IPNS).

Effect of organic and inorganic on mean weight diameter (MWD), water stable aggregates (WSA %, >0.25 mm), geometric mean diameter (GMD) and aggregate ratio at 0-7.5 cm soil depth
The table 3 represents the effect fertilizer application using STCR approach with and without IPNS on WSA and MWD. Maximum mean weight diameter, aggregate ratio and water stable aggregates(0.226, 0.112 and 9.27 per cent, respectively) were observed in the treatment T_5 (*i.e.*Target yield 20 q ha^{-1} with IPNS) and lowest mean weight diameter (1.88) was found under the treatment T_2 (*i.e.*Target yield 15 q ha^{-1}), lowest water stable aggregate and aggregate ratio (3.88 per cent and 0.015 respectively) was found under T_4 (*i.e.*Target yield 20 q ha^{-1}) and lowest (0015) was found under the treatment T_4 and in the 0-7.5 cm soil depth. Highest geometric mean diameter (0.795) was found under the treatment T_1 (*i.e.*general recommended dose) and lowest (0.725) geometric mean diameter value was found under the treatment T_5 (*i.e.*Target yield 20 q ha^{-1} with IPNS)

Table 1: Effect of organic and inorganic on aggregate size fraction and organic carbon content (g C kg^{-1} soil) in soil at 0-7.5 cm soil depth

Treatments	<0.1 Mm	0.1 mm	0.25 mm	0.50 mm	2.0 mm
T_1-General recommended dose	3.05	15.20	0.808	0.827	0.119
T_2-Target yield 15 q ha^{-1}	2.14	16.48	1.031	0.312	0.029
T_3-Target yield 15 q ha^{-1} with IPNS	0.90	16.63	1.912	0.445	0.107
T_4-Target yield 20 q ha^{-1}	1.59	16.95	1.174	0.261	0.028
T_5-Target yield 20 q ha^{-1} with IPNS	2.17	14.60	1.224	1.115	0.894
SEm+	0.122	0.14	0.092	0.034	0.033
Cd (P = 0.05)	0.375	0.44	0.284	0.104	0.101

Table 2: Effect of organic and inorganic on macro, meso and micro aggregate in soil at 0-7.5 cm soil depth

Treatments	CMaA >2000 µm	CMesoA 2000-500µm	CMesoA 500-250µm	CMicA 250-100µm
T_1-General recommended dose	0.060	4.13	4.04	75.99
T_2-Target yield 15 q ha^{-1}	0.015	1.56	5.16	82.42
T_3-Target yield 15 q ha^{-1} with IPNS	0.054	2.23	9.56	83.17
T_4-Target yield 20 q ha^{-1}	0.014	1.31	5.87	84.76
T_5-Target yield 20 q ha^{-1} with IPNS	0.447	5.58	6.12	73.00
SEm+	0.016	0.17	0.46	0.71
Cd (P = 0.05)	0.050	0.52	1.42	2.20

* CMacA>2000 µm – per cent coarse macro size aggregate, CMesoA** 2000-500 µm – per cent coarse meso size aggregate, CMesoA 500-250 µm – per cent coarse meso size aggregate CMicA 250-100 µm – per cent micro size aggregate.

Table 3: Effect of organic and inorganic on aggregate indices at 0-7.5 cm soil depth

Treatments	MWD (mm)	WSA (%)	GMD (mm)	AR
T_1-General recommended dose	0.207	6.68	0.795	0.050
T_2-Target yield 15 q ha^{-1}	0.188	3.88	0.787	0.017
T_3-Target yield 15 q ha^{-1} with IPNS	0.211	6.37	0.731	0.028
T_4-Target yield 20 q ha^{-1}	0.191	3.83	0.771	0.015
T_5-Target yield 20 q ha^{-1} with IPNS	0.226	9.27	0.725	0.112
SEm+	0.002	0.15	0.004	0.001
Cd (P = 0.05)	0.005	0.46	0.011	0.003

*MWD- Mean weight diameter, GMD-geometric mean diameter, WSA per cent water stable aggregate, AR- aggregate ratio

Effect of organic and inorganic on coarse macro-, coarse meso-, coarse meso- and micro size aggregate at 7.5-15 cm soil depth
In the table 5 indicated the coarse macro size aggregate, coarse meso size aggregate, coarse meso size aggregate and micro size aggregate in per cent. Highest mean value of coarse macro size aggregate, coarse meso size aggregate were found the under the treatment T_5 (*i.e.*Target yield 20 q ha^{-1} with IPNS) and lowest mean value ofcoarse macro size aggregate and coarse meso size aggregate were found under the treatment T_4 (*i.e.*Target yield 20 q ha^{-1}).
Highest mean value of coarse meso size aggregate was found under the treatment under treatment T_3 (*i.e.*Target yield 15 q ha^{-1} with IPNS) and lowest mean value was found under the treatment T_1 (*i.e.*General recommended dose). The highest mean value of micro size aggregate was found under the treatment T_4 (Target yield 20 q ha^{-1}) and lowest value of micro size aggregate was found under the treatment T_5 (Target yield 20 q ha^{-1} with IPNS).

Effect of organic and inorganic on mean weight diameter (MWD), water stable aggregates (WSA %, >0.25 mm) geometric mean diameter (GMD) and aggregate ratio at7.5-15 cm soil depth

The table 6 represented the effect of fertilizer application using STCR approach with and without IPNS on WSA and MWD. Maximum mean weight diameter, aggregate ratio and water stable aggregates (0.218, 0.090 and 7.96 per cent, respectively) were observed in the treatment T_5 (*i.e.*Target yield 20 q ha^{-1} with IPNS) and lowest mean weight diameter and water stable aggregate (0.185 and 3.30 per cent respectively) was found under the treatment T_2 (*i.e.*Target yield 15 q ha^{-1}), lowest aggregate ratio (0.013) was found under T_4 (*i.e.*Target yield 20 q ha^{-1}). Highest geometric mean diameter (0.788) was found under the treatment T_2 (*i.e.*Target yield 15 q ha^{-1}) and lowest (0.737) geometric mean diameter value was found under the treatment T_5 (*i.e.*Target yield 20 q ha^{-1} with IPNS)

Table 4: Effect of STCR approach on aggregate size fraction and organic carbon content (g C kg^{-1} soil) in soil at 7.5-15 cm soil depth

Treatments	<0.1 mm	0.1 mm	0.25 mm	0.50 mm	2.0 Mm
T_1-General recommended dose	2.51	15.93	0.80	0.666	0.090
T_2-Target yield 15 q ha^{-1}	2.02	16.80	0.90	0.260	0.025
T_3-Target yield 15 q ha^{-1} with IPNS	1.07	16.81	1.58	0.444	0.095
T_4-Target yield 20 q ha^{-1}	1.65	17.07	1.02	0.239	0.024
T_5-Target yield 20 q ha^{-1} with IPNS	2.03	15.26	1.08	0.948	0.686
SEm+	0.27	0.30	0.14	0.103	0.088
Cd (P = 0.05)	0.84	0.93	0.43	0.317	0.270

Table 5: Effect of STCR approach on macro, meso and micro aggregate in soil at 7.5-15 cm soil depth

Treatments	CMaA>2000µm	CMesoA 2000-500µm	CMesoA 500-250µm	CMicA 250-100µm
T_1-General recommended dose	0.045	3.33	4.00	79.65
T_2-Target yield 15 q ha^{-1}	0.013	1.30	4.48	84.00
T_3-Target yield 15 q ha^{-1} with IPNS	0.047	2.22	7.92	84.03
T_4-Target yield 20 q ha^{-1}	0.012	1.19	5.09	85.35
T_5-Target yield 20 q ha^{-1} with IPNS	0.343	4.74	5.42	76.28
SEm+	0.044	0.51	0.70	1.50
Cd (P = 0.05)	0.135	1.59	2.16	4.63

* CMacA>2000 µm – per cent coarse macro size aggregate, CMesoA** 2000-500 µm – per cent coarse meso size aggregate, CMesoA 500-250 µm – per cent coarse meso size aggregate CMicA 250-100 µm – per cent micro size aggregate.

Table 6: Effect of STCR approach on aggregate indices at 7.5-15 cm soil depth

Treatments	MWD (mm)	WSA (%)	GMD (MM)	AR
T_1-General recommended dose	0.202	5.66	0.787	0.040
T_2-Target yield 15 q ha^{-1}	0.185	3.30	0.788	0.014
T_3-Target yield 15 q ha^{-1} with IPNS	0.207	5.75	0.742	0.028
T_4-Target yield 20 q ha^{-1}	0.187	3.40	0.776	0.013
T_5-Target yield 20 q ha^{-1} with IPNS	0.218	7.96	0.737	0.090
SEm+	0.004	0.47	0.009	0.010
Cd (P = 0.05)	0.012	1.45	0.027	0.030

*MWD- Mean weight diameter, GMD-geometric mean diameter, WSA per cent water stable aggregate, AR- aggregate ratio

The organic matter having an important binding agent for aggregation and is reliable for the formation and durability of soil aggregates (Tisdall and Oades. 1982) [38] through biotic contrivence (Schjonning *et al.*, 2006) [31]. The added organics material could provide extra fresh organic materials (water soluble and hydrolysable substrates) and due to soil organic carbon produce of microbial polysaccharides that enhance aggregate cohesion. This explained the noticed progressive enhanced in aggregate stability to mechanical disintegration. Positive effects of IPNS application on aggregate stability have been reported in a number of studies (Boix-Fayos *et al.*, 2001; Barzegar *et al.*, 2002; Haghighi *et al.*, 2010; Bandyopadhyay *et al.*, 2010; Singh *et al.*, 2007, and Singh *et al.*, 2015) [4, 2, 14, 1, 34, 33]. The percent of large macro aggregates enclosed by the total soil aggregates is the most vital fraction to evaluate the effect of management manner on soil aggregation, because it exerts a great influence on the MWD, a comprehensive index for assesing soil aggregation (Jiao *et al.*, 2006) [19]. Again, higher crop residue carbon might have an effect on aggregate stability as plant roots are major binding factors at the scale of macro aggregates (Six *et al.*, 2004) [35]. The presence of soil microbial population may also influence aggregate formation (Six *et al.*, 2005) [36].

Conclusion

From the result of this study, it was found out that the organic treated soils are more stable and therefore more aggregated compared to the inorganic treated soils.

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