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DD Fulpagare
Ph.D. Research Scholar, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

NJ Ranshur
Chief Scientist and Associate Director of Research, Zonal Agriculture Research Station, Solapur, Maharashtra, India

Ritu S Thakare
Professor, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

SR Patil
Associate Dean, College of Agriculture, Karad, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

AG Durgude
Analytical Chemist, Micronutrient Research Scheme, Department of Soil Science & Agril. Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

MR Patil
Associate Professor, Department of Statistics, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Corresponding Author:
DD Fulpagare
Ph.D. Research Scholar, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Studies on aggregate stability of soils of Solapur district and their correlation with soil organic carbon and available nitrogen

DD Fulpagare, NJ Ranshur, Ritu S Thakare, SR Patil, AG Durgude and MR Patil

Abstract
The studies on aggregate stability in soils of Solapur district and their correlation with soil organic carbon and available nitrogen was executed during 2022. Total 30 soil samples were systematically collected from the surface layer from the depth of 0-15 cm, and the precise spatial coordinates of the sampled sites were recorded by GPS device. The findings revealed that about 17 (56.67%) samples reported poor aggregate stability (MWD) and only 13 (43.33%) samples reported good aggregate stability. The bulk density of analyzed soil samples ranged between 1.38-1.52 Mg m^{-3} with an average value of 1.45 Mg m^{-3}. The content of available nitrogen, available phosphorus and available potassium in soils of Solapur district varied from 120.0-203.1 kg ha^{-1}, 3.9-16.3 kg ha^{-1} and 235.2-571.2 kg ha^{-1}, respectively. Similarly, the concentration of soil organic carbon, and their different fractions such as water soluble carbon (WSC), soil microbial biomass carbon (SMBC), permanganate oxidisable soil carbon (POSC), particulate organic matter carbon (POMC), humic acid carbon, fulvic acid carbon and total organic carbon (TOC) varied from 3.0-8.25 g kg^{-1} soil, 2.92-6.06 $mgkg^{-1}$, 132.86-335.18 mg kg^{-1}, 299.25-654.75 mg kg^{-1}, 1.23-2.37 g kg^{-1}, 80.88-139.71 g kg^{-1}, 42.65-117.65 g kg^{-1} and 5.15-18.45 g kg^{-1}, respectively.

Keywords: Aggregate stability, mean weight diameter (MWD)

1. Introduction

Soil is a complex and dynamic natural entity intrinsic to Earth's biosphere, assumes a multifaceted array of roles within its ecological framework. It serves as a reservoir, of both water and indispensable nutrients, thereby undertaking a pivotal function in the intricate process of water purification. This central role further extends to encompass its involvement as a center for the degradation of organic matter and potentially harmful substances. Moreover, the intricate interplay of soil in the carbon cycle designates it as foundational constituent in Earth's biogeochemical phenomena. In tandem with these functions, soil manifests notable proficiencies, including facilitation of ground water recharge, mediation of soil porosity to enhance aeration, provision of essential nutrients to organisms, and offering a habitat for microbial life (Deshmukh, 2012) [4]. This complex relationship between soil properties and regional characteristics brings us to study the concept of soil aggregate stability.

Specifically, the capacity of soil aggregates to withstand disintegration when subjected to disruptive forces such as raindrops, tillage, and erosion is called aggregate stability etc. Practically, this property plays a pivotal role in soil sustainability and productivity (Singh *et al.*, 2007) [14]. Moreover, it serves as a crucial important indicator of soil quality and health assessment, because it reflects the combined influence of various physical, chemical, and biological properties of soil (Doran *et al.*, 1996) [5].

Earlier studies have frequently underscored the intricate connection between soil organic carbon and aggregate stability (Feller *et al.*, 2001) [6]. These investigations have also revealed that the organic matter functions not only as a binding agent in aggregate formation but also performs supplementary roles in bolstering its stability. Additionally, aggregates not only sequester carbon but also provide protection against microbial, physiochemical, and enzymatic degradation (Lal *et al.*, 2003; Bajracharya *et al.*, 1998) [11, 2]. Organic matter is the most valuable source of organic carbon in soil that obtained from partial and fully decomposed plants and animal debris. According to time of persistence in soil aggregates, soil organic matter/carbon can be divided in to three main groups *viz.*, a) transient or labile carbon fraction (polysaccharides and carbohydrates), b) temporary (fungal hyphae and plant roots).

(Tisdall and Oades, 1982) [15] and c) persistent or stable carbon fraction (humic substances which are more resistant aromatic compounds that are associated with polyvalent cations) (Amézketa, 1999) [1]. Among these three groups transient and persistent organic substances helps in stabilization of micro-aggregates (< 0.25 mm) where as temporary organic substances helps in stabilization of macro-aggregates (> 0.25 mm) (Amézketa, 1999 [1]; Tisdall and Oades, 1982) [15]. The comprehensive scientific study of aggregate stability and its correlation with soil available nitrogen and organic carbon in Solapur district of Western Maharashtra is imperative to enhance soil aggregate stability, carbon stocks, and nitrogen content in soils.

2 Materials and Methods

2.1 Study Area: The Solapur district situated in south eastern edge of state of Maharashtra and lies between 17° 10´ to 18° 32´ N latitude and 74° 42´ to 76° 15´ E longitude at an average elevation of 458 m from MSL. The district occupied 14895 sq. km. area which is 4.82 percent of the total area of Maharashtra state (Reshma *et al.* 2020 [13] and Hadole *et al.* 2020) [9].

2.2 Soil Characteristics: Predominant soils in this region are medium to deep black and deep brown to red, primarily derived from Deccan volcanic basalt rocks.

2.3 Climate: The district poses dry and hot climate except rainy season. However, mean maximum and mean minimum temperature ranged between 13 °C to 40 °C, respectively. The district falls under rain shadow zone of the state and on an average it received 625 mm rainfall per annum (Reddy, 2013) [12].

3 Results and Discussion

3.1 Physical Properties of Soils of Solapur District: The data regarding to the physical properties (colour, texture, aggregate stability (MWD) and bulk density) of soil samples collected from Solapur district were presented in Table 1.

3.1.1 Soil Colour: The obtained results showed that out of total soil samples of Solapur district, about 9 (30.0%) samples were reported dark brown (4 of 10 YR 3/2, 4 of 10 YR 3/3 and 1 of 7.5 YR 3/3) in colour that are collected from different locations *viz*., Laxmi Takli and Sharadrenagar Takli (Pulses & Oilseed Research Center) of Pandharpur tehsil, Bamani and Burange Wadi of Sangole tehsil, Waddegaon and Kamti Bk. of Mohal tehsil, Dongaon, Phisare and Malshiram (Khudus) in North Solapur, Karmala and Malshiras tehsils, respectively. About 5 (16.67%) samples were reported very dark grayish brown (10 YR 3/2) that are collected from Dharamgaon, Mangi and Sawaleshwar locations of Mangalvedha, Karmala and Mohol tehsils and Mardi and Paniv locations of Malshiras tehsil, respectively. About 3 (10.0%) samples reported very dark brown (2 of 10 YR 2/2 and 1 of 10 YR 3/2) in colour which were fetched from Mangalvedha and Tandor locations of Mangalvedh tehsil and Vadapur location of South Solapur tehsil, respectively. Another 3 (10.0%) samples reported very dark gray (10 YR 3/1) in colour which were fetched from telgaon and Mulegaon (ZARS) locations of North Solapur and Mohal KVK of Mohal tehsil, respectively. About 2 (6.70%) samples recognized Dark grayish brown (10 YR 4/2) in colour that were collected from Mhada Uplai Kh. and Wani Chinchole locations of Mhada and Sangole tehsils, respectively. Only one (3.33%) sample fetched from Anawali village location of Mangalvedha tehsil reported redish brown (5 YR 4/3) in colour. More 4 (13.33%) samples recognized brown (2 of 10 YR 4/3, 1 of 7.5 YR 4/2 and 1 of 7.5 YR 5/3) soil colour that were collected from Khardi and Mulegaon (Divisional Agril. Research Center) locations of Pandharpur and North Solapur tehsils, as well as Jawala and Lonavire locations of Sangola tehsil, respectively. Another 3 soil samples collected from Bhosare, Kacharewadi and Kandalgaon locations of Mhada, Mangalvedha and South Solapur tehsils, respectively reported three distinct colours *viz*., dark yellowish brown (10 YR 4/4), light olive brown (2.5 Y 5/4) and yellowish brown (10 YR 5/4), respectively.

The colour variations in soils might be due to type parent material, amount and forms of organic matter or carbon, climatic conditions and availability of moisture in particuler area and types of vegetation etc. Dark shades of soil colour might be due to the decomposition status of organic matter and types and amount of clays present in soils. Smectite types of clay minerals contributing in increasing total surface area and which expected to retain more organic carbon or matter and also contribute darkening soil colour. The soils of Solapur district predominantly developed from basalt rocks due to which it contains more smectite types of clay minerals and this minerals form a complexes with organic matters and developed brown to very dark brown colour of soils. Bhattachayya *et al.* (2013) [3] reported that Vertisols soil orders have more amounts of clays and silts rather than sand which contribute to increase the surface area and decrease in coloure value of soils. The findings are conformity with those reported by Ghodke *et al.* (2016) [7].

3.1.2 Soil Texture: The recorded observations revealed that among all soil samples of Solapur district, clayey texture was reported in 11 (36.67%) samples collected from Lakshmi Takli, Sharadrenagar Takli (PORC) locations of Pandharpur tehsil, Dharamgaon, Mangalvedha Tandor locations of Mangalvedha tehsil, Telgaon and Mulegaon (ZARS) locations of North Solapur and Vadapur, Mohal KVK, Madhaa Uplai Kh and Mangi locations of South Solapur, Mohal, Mhada and Karmala tehsils, respectively. The clay loam soil texture was reported in total 8 (26.67%) soil samples that were collected from Anawali, Bamani, Kharadi and Sawaleshwar locations of Mangalvedha, Sangola, Pandharpur and Mohal tehsils, respectively whereas, Dongaon and Mulegaon (Dvisional Agril. Research Center) locations of North Solapur tehsil and Mardi and Paniv locations of Malshiras tehsil, respectively. The loam texture of soil were reported in total 7 (23.33%) soil samples collected from various locations *viz*., Wani Chinchole, Burange Wadi and Jawala locations of Sangole tehsil, Phisare and Malshiram (Khudus) locations of Karmala and Malshiras tehsil, whereas, Waddegaon and Kanti Bk locations of Mohal tehsil etc. The sandy clay texture was reported in only 1 (3.33%) sample that was fetched from Bhosare location of Mhada tehsil. The sandy loam textural class was reported in 3 (10.0%) different samples collected from Kacharewadi, Lonavire and Kandalgaon locations of Mangalvedha, Sangole and South Solapur tehsils, respectively.

The wide textural variation has been observed in Solapur district. It might be due to different types of soil forming factors such as parent materials, vegetation, climate and topography etc. mainly responsible for soil formation in this region. The findings in respect of soil textural classes reported in Solapur district are in corroborated with Kharche and Pharande (2010) [10] and Ghodke *et al.* (2016) [7].

3.1.3 Aggregate Stability of Soil (Mean Weight Diameter):

The data in Table 1 revealed that the aggregate stability (MWD) of soils of Solapur district varied from 0.11-1.91 mm with mean of 0.99 mm. Among all collected soil samples of Solapur district, the least (0.11 mm) and high (1.91 mm) aggregate stability (MWD) were recorded in Kandalgaon and Bamani village locations of South Solapur and Sangole tehsils of conserned district, respectively.

According to classification criteria total 17 (56.67%) soil samples fetched from different locations namely, Laxmi Takli and Khardi locations of Pandharpur tehsil, Mangalvedha and Kacharewadi locations of Mangalvedha tehsil, Telgaon and Mulegaon (ZARS) locations of North Solapur tehsil, Mangi location of Karmala tehsil, as well as Sawaleshwar, Waddegaon and Kamti Bk locations of Mohal tehsil, Paniv and Malshiram (Khudus) locations of Malshiras tehsil, along with Wani Chinchole, Burange wadi and Lonavire locations of Sangole tehsil whereas Bhosare and Kandalgaon locations of South Solapur tehsil were reported less than 1 mm Mean Weight Diameter (MWD) that indicates poor aggregate stability of analyzed soils. However, only about 13 (43.33%) soil samples collected from Shadrenagar Takli (PORC), Vadapur, Mohal KVK, Madha Uplaon Kh, Mardi and Phisare locations of Pandharpur, South Solapur, Mohal, Mhada, Malshiras and Karmala tehsils, respectively were reported MWD > 1 mm that indicated good aggregate stability of soils.

The obtained findings indicated that almost 56.67 percent samples confirmed MWD less than 1mm that indicates poor aggregate stability. It might be due to lack of cementing agents specifically soil organic matter or carbon, high decomposition rate of organic matter due to elevated temperature, on and off field crop residues burning rather than its retention, uncontrolled irrigation management practices caused leaching of bases, monocroping and exploitation of multivalent cations (Ca^{++}, Mg^{++}, Al^{+++}) that helps in soil aggregation phenomenon etc.

The ultracarefull study of soil aggregate stability (MWD) in relation to soil texture was performed and observed that the fine textured class (clay, silty clay, silty clay loam and clay loam) had highest average MWD i.e. 1.20 mm (> 1 mm) represent stable soil aggregates. In contrast, the medium textured class (loam and sandy clay) and the coarse textured class (sandy loam) of soils reported on an average MWD of 0.71 mm and 0.43 mm, (< 1 mm), respectively, represent poor stability of soil aggregates. Study elucidated that soils with finer textures tend to exhibit greater stability of aggregates compared to those with medium and coarse textures.

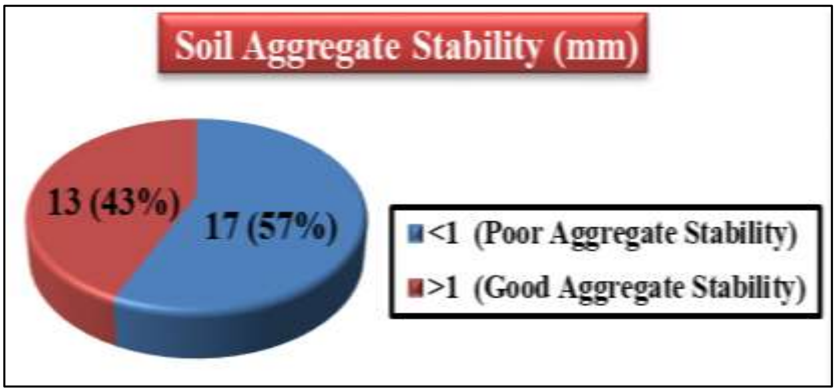

Fig 1: Soil Aggregate Stability (MWD)

3.1.4 Bulk Density of Soil

The finding about bulk density of collected soil samples from several locations in Solapur districts was depicted in Table 1. The data showed that the bulk density of analysed soil samples ranged between 1.38-1.52 Mg m^{-3} with an average value of 1.45 Mg m^{-3}. In this the minimum (1.38 Mg m^{-3}) and maximum (1.52 Mg m^{-3}) readings of soil bulk density has been recorded in Telgaon and Kandalgaon villages of North Solapur and South Solapur tehsils of Solapur district, respectively.

The mean value of bulk density of assessed soil samples found to be quite high than the normal soils. It might be due to presence of heavy clay minerals, low organic matter and history of compaction by heavy machineries etc.

More close analysis was conducted to examine the relationship between soil texture and bulk density by utilizing available data. The study's revealed that there were no significant differences in bulk density with respect to soil texture. Specifically, the average bulk density values for soils classified as fine textured (clay, silty clay, silty clay loam and clay loam), medium textured (loam to sandy clay) and coarse textured (sandy loam to sandy) were found to be 1.45, 1.45 and 1.47 Mg m^{-3}, respectively. These results demonstrated a notable similarity in bulk density among the different soil texture classes.

3.2 Chemical Properties of Soils of Solapur District

The data analysis of chemical properties of soil samples collected from Solapur district is summarized in Table-2.

Table 1: Physical Properties of Soils of Solapur District

Sr. No.	Tehsil	Village	Latitude	Longitude	Soil Colour	Soil Textural Class	MWD (mm)	BD (Mg m^{-3})
1	Pandharpur	Lakshmi Takli	17°38'48.2"N	75°18'18.1"E	10 YR 3/2 (Dark Brown)	Clay	0.89	1.48
2	Pandharpur	Sharadrenagar Takli (PORC)	17°39'35.4"N	75°17'52.5"E	10 YR 3/2 (Dark Brown)	Clay	1.03	1.39
3	Mangalvedha	Dharamgaon	17°32'42.7"N	75°26'46.1"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay	1.59	1.39
4	Mangalvedha	Mangalvedha	17°30'32.3"N	75°27'45.9"E	10 YR 2/2 (Very Dark Brown)	Clay	0.79	1.51
5	Mangalvedha	Tandor	17°31'18.1"N	75°36'41.4"E	10 YR 2/2 (Very Dark Brown)	Clay	1.29	1.42
6	South Solapur	Vadapur	17°32'15.8"N	75°40'09.5"E	10 YR 3/2 (Very Dark Brown)	Clay	1.86	1.39
7	North Solapur	Telgaon	17°36'12.0"N	75°48'15.1"E	10 YR 3/1 (Very Dark Gray)	Clay	0.91	1.38
8	North Solapur	Mulegaon (ZARS)	17°41'23.6"N	75°56'58.9"E	10 YR 3/1 (Very Dark Gray)	Clay	0.80	1.48
9	Mohal	Mohal, KVK	17°49'07.2"N	75°37'40.6"E	10 YR 3/1 (Very Dark Gray)	Clay	1.03	1.51
10	Mhada	Madha Uplai Kh.	18°00'39.7"N	75°31'17.5"E	10 YR 4/2 (Dark Grayish Brown)	Clay	1.60	1.49
11	Karmala	Mangi	18°28'49.3"N	75°11'32.4"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay	0.86	1.46
12	Mangalvedha	Anawali	17°36'53.8"N	75°23'01.5"E	5 YR 4/3 (Redish Brown)	Clay Loam	1.31	1.48
13	Sangole	Bamani	17°28'53.3"N	75°13'39.9"E	10 YR 3/2 (Dark Brown)	Clay Loam	1.91	1.42
14	Pandharpur	Khardi	17°35'03.1"N	75°16'32.5"E	7.5 YR 4/2 (Brown)	Clay Loam	0.84	1.44
15	North Solapur	Dongaon	17°37'42.7"N	75°51'25.0"E	7.5 YR 3/3 (Dark Brown)	Clay Loam	1.85	1.44
16	North Solapur	Mulegaon (Div. Agril. Res. Cent.)	17°41'13.0"N	75°57'13.0"E	10 YR 4/3 (Brown)	Clay Loam	1.39	1.45
17	Mohal	Sawaleshwar	17°45'37.5"N	75°45'52.1"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay Loam	0.83	1.52
18	Malshiras	Mardi	17°49'14.9"N	75°53'22.4"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay Loam	1.15	1.42
19	Malshiras	Paniv	17°50'27.1"N	74°58'21.3"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay Loam	0.79	1.47
20	Sangole	Wani Chinchole	17°20'43.6"N	75°18'36.1"E	10 YR 4/2 (Dark Grayish Brown)	Loam	0.39	1.48
21	Sangole	Burange Wadi	17°18'34.2"N	75°11'18.8"E	10 YR 3/2 (Dark Brown)	Loam	0.60	1.46
22	Sangole	Jawala	17°19'42.5"N	75°14'10.4"E	10 YR 4/3 (Brown)	Loam	1.17	1.40
23	Karmala	Phisare	18°20'30.8"N	75°16'12.8"E	10 YR 3/3 (Dark Brown)	Loam	1.13	1.47
24	Mohal	Waddegaon	17°37'00.7"N	75°34'49.0"E	10 YR 3/3 (Dark Brown)	Loam	0.77	1.47
25	Mohal	Kamti BK.	17°38'55.9"N	75°42'35.6"E	10 YR 3/3 (Dark Brown)	Loam	0.74	1.42
26	Malshiras	Malshiram (Khudus)	17°47'02.3"N	74°59'10.1"E	10 YR 3/3 (Dark Brown)	Loam	0.72	1.44
27	Mhada	Bhosare	18°06'59.6"N	75°24'53.9"E	10 YR 4/4 (Dark Yellowish Brown)	Sandy Clay	0.20	1.49
28	Mangalvedha	Kacharewadi	17°28'37.9"N	75°24'55.7"E	2.5 Y 5/4 (Light Olive Brown)	Sandy Loam	0.30	1.45
29	Sangole	Lonavire	17°18'21.1"N	75°10'52.8"E	7.5 YR 5/3 (Brown)	Sandy Loam	0.87	1.45
30	South Solapur	Kandalgaon	17°33'17.4"N	75°45'56.0"E	10 YR 5/4 (Yellowish Brown)	Sandy Loam	0.11	1.52
	Max						1.91	1.52
	Min						0.11	1.38
	Mean						0.99	1.45
	St. Dev.						0.47	0.04
	CV						47.06	2.77

3.2.1 Soil pH

In the Table 2 the status of pH of collected soil samples from several locations in the Solapur district is presented. The analysed data pertaining to soil pH cleared that the pH of soils in Solapur district ranged between 6.85 - 8.17 with an average value of 7.49 Among all samples the lowest (6.85) and highest (8.17) pH of soils were reported in Bhosare and Tandor villages of Mhada and Mangalwedha tehsils of Solapur district, respectively. However, among all 30 analysed soil samples of Solapur district, about 18 (60.0%) samples took from different sites *viz.*, Sharadrenagar Takli (PORC) of Pandharpur tehsil, Dharamgaon, Tandor and Anawali locations of Mangalwedha tehasil. Whereas, Vadapur, Mohal KVK, Madha Uplain Kh., Mardi and Phisare locations of South Solapur, Mohal, Mhada, Malshiras and Phisare tehsils respectively. Additionally, Bamani and Jawala of Sangole tehsil and Dongaon and Mulegaon (Div. Agril. Res. Cent. Of North Solapur tehsil respectively found to be neutral (pH 6.5-7.5) in pH. However, about 12 (40.0%) samples fetched from Lakmi Takli, location of Pandharpur tehsil, Dharangaon and Tandor locations of Mangalvedha tehsil, Mangi and Phisare locations of Karmala tehsil, Bamani, Burangewadi locations of Sangole tehsil, Sawaleshwar and Waddegaon locations of Mohal tehsil as well as Mardi and Paniv locations of Malshiras tehsil were found to be alkaline (pH >7.5) in pH. Above findings implicated that the soils of Solapur district are neutral to alkaline in reaction. It might be due to the types of parental material (basaltic), saturation of bases, amount of rainfall, changes in land use pattern and frequent use of basic chemical fertilizers. Intensive scrutiny of the relationship between soil pH and soil texture did not reveal any substantial variations.

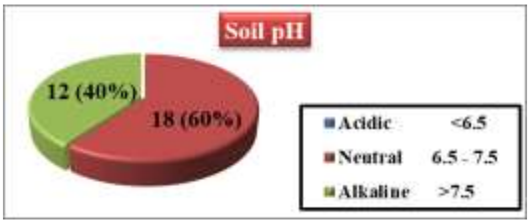

Fig 2: Soil pH

3.2.2 Electrical Conductivity (dS m^{-1})

The data pertaining to electrical conductivity (EC) of analysed soils samples depicted in Table 2. The obtained data concluded that the electrical conductivity of soils of Solapur district ranged from 0.15 - 0.85 dS m^{-1} with the mean of 0.28 dS m^{-1}. Among all 30 samples the minimum (0.15 dS m^{-1}) and maximum (0.85 dS m^{-1}) electrical conductivity has been recorded in Mulegaon and Sawaleshwar villages of North Solapur and Mohal tehsils, respectively. However, all samples showed electrical conductivity (EC) of less than 1 dS m^{-1} hence, all samples categorized in to normal soil category. These findings were consistent with previous results by Ghodke *et al.* (2016) [7] and Reshma *et al.* (2020) [13]. Further extensive investigation into the relationship between electrical conductivity (EC) and texture of soil did not unveil any noteworthy variations.

Table 2: Chemical Properties of Soils of Solapur District

Sr. No.	Tehsil	Village	pH	EC (dS m^{-1})	$CaCO_3$ (%)	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})
1	Pandharpur	Lakshmi Takli	7.65	0.46	5.50	174.3	4.0	324.8
2	Pandharpur	Sharadrenagar Takli (Pulses & Oilseed Rese. Cent.)	7.48	0.19	7.25	158.3	10.5	347.2
3	Mangalvedha	Dharamgaon	7.71	0.28	9.38	203.1	9.5	369.6
4	Mangalvedha	Mangalvedha	7.39	0.30	2.13	126.3	5.1	336.0
5	Mangalvedha	Tandor	8.17	0.33	6.25	148.7	9.1	313.6
6	South Solapur	Vadapur	7.13	0.44	3.75	151.9	8.6	448.0
7	North Solapur	Telgaon	7.50	0.18	2.38	167.9	7.3	324.8
8	North Solapur	Mulegaon (ZARS)	7.06	0.19	10.00	148.7	14.0	347.2
9	Mohal	Mohal KVK	7.21	0.20	5.88	161.5	16.3	369.6
10	Mhada	Madha Uplai Kh.	7.38	0.19	0.25	174.3	12.5	459.2
11	Karmala	Mangi	7.74	0.20	6.88	177.5	9.0	560.0
12	Mangalvedha	Anawali	7.45	0.21	8.50	183.9	7.6	291.2
13	Sangole	Bamani	7.54	0.34	8.88	177.5	8.7	313.6
14	Pandharpur	Khardi	7.47	0.45	6.00	183.9	7.9	470.4
15	North Solapur	Dongaon	7.11	0.17	1.25	177.5	13.1	459.2
16	North Solapur	Mulegaon (Div. Agril. Res. Cent.)	7.09	0.15	2.13	174.3	14.1	481.6
17	Mohal	Sawaleshwar	7.82	0.85	5.75	151.9	7.5	324.8
18	Malshiras	Mardi	7.95	0.34	7.70	167.9	6.6	504.0
19	Malshiras	Paniv	7.89	0.29	5.00	174.3	13.5	436.8
20	Sangole	Wani Chinchole	7.44	0.19	7.13	171.1	12.6	392.0
21	Sangole	Burange Wadi	7.62	0.18	6.63	171.1	13.4	324.8
22	Sangole	Jawala	7.40	0.22	7.75	177.5	13.6	302.4
23	Karmala	Phisare	7.52	0.18	9.63	155.1	9.9	481.6
24	Mohal	Waddegaon	7.75	0.30	5.50	148.7	6.0	537.6
25	Mohal	Kamti BK.	7.50	0.31	5.60	151.9	10.1	515.2
26	Malshiras	Malshiram (Khudus)	7.74	0.19	4.90	158.3	4.4	436.8
27	Mhada	Bhosare	6.85	0.16	8.38	174.3	9.4	571.2
28	Mangalvedha	Kacharewadi	7.32	0.31	2.13	120.0	4.3	235.2
29	Sangole	Lonavire	7.46	0.28	7.25	174.3	7.2	246.4
30	South Solapur	Kandalgaon	7.46	0.25	10.38	135.9	3.9	246.4
	Max		8.17	0.85	10.38	203.1	16.3	571.2
	Min		6.85	0.15	0.25	120.0	3.9	235.2
	Mean		7.49	0.28	6.00	164.1	9.3	392.4
	St. Dev.		0.29	0.14	2.71	17.9	3.4	96.7
	CV		3.84	50.05	45.17	10.9	37.0	24.7

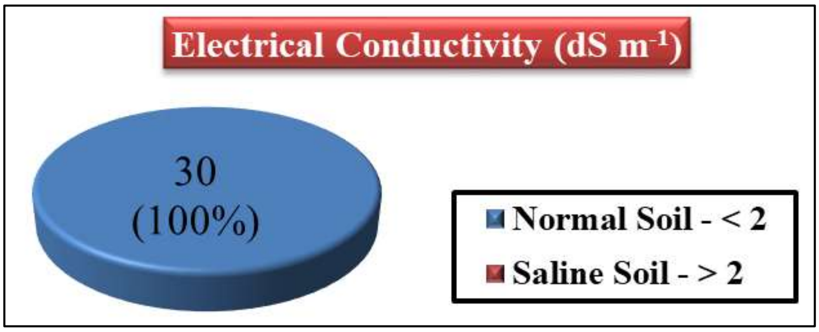

Fig 3: Soil Electrical Conductivity

3.2.3 Calcium Carbonate (%)

The findings regarding to calcium carbonate content in soils of Solapur district were displayed in Table 2. The data divulge that the percent $CaCO_3$ of analyzed soil samples varied from 0.25 to 10.38 percent with a mean value of 6.0 percent. Among all 30 samples the lower (0.25%) and higher (10.38%) were noted in Madha Uplai Kh. and Kandalgaon villages of Mhada and South Solapur tehsils of same district.

Out of 30 soil samples of Solapur district about 1 sample (3.33%) reported very low (< 0.5%) and 1 sample (3.33%) reported moderate (1.10-2.0%) in calcium carbonate content of soils. Whereas, the groups of about 7 samples (23.33%), 20 samples (66.67%) samples were categorized in moderately high (2.10-5.0%) and high (5.1-10%) calcium carbonate content and only 1 sample (3.33%) were reported very high (> 10%) calcium carbonate content. The current findings probably because of predominance of arid to semiarid climatic conditions and precipitation of calcium carbonate in surface layer of soils. The equivalent range of observations had been also recorded by Reshma *et al.* (2020) [13].

Further close study observed that the medium textured class (loam and sandy clay) of soils resulted on an average highest calcium carbonate content i.e. 6.94 percent and course textured class (sandy loam) of soils observed on an average 6.58 percent. Whereas fine textured class (clay and clay loam) of soil estimated on an average lowest calcium carbonate content i.e. 5.52 percent.

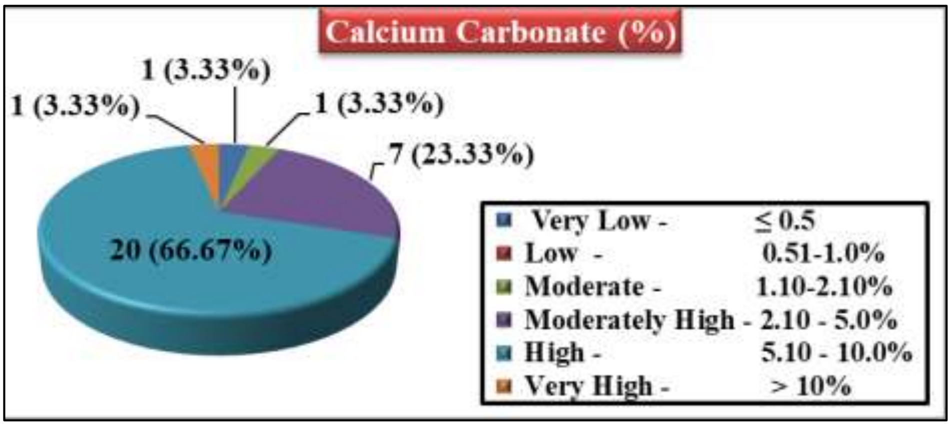

Fig 4: Calcium Carbonate (%)

3.2.4 Soil Available Nitrogen, Phosphorus and Potassium

The findings in respect of soil primary macro nutrients (*viz*., available nitrogen, phosphorus and potassium) depicted in Table 2.

3.2.4.1 Soil Available Nitrogen

The data depicted in Table 2 revealed that the soil available nitrogen content in the soils of Solapur district ranged between 120.0 to 203.1 kg ha^{-1} with an average value of 164.1 kg ha^{-1}. Out of all soil sample of Solapur district the lowest (120.0 kg ha^{-1}) and highest (203.1 kg ha^{-1}) available nitrogen content in soils were reported in Kacharewadi and Dharamgaon villages of Mangalvedha tehsil of Solapur district, respectively.

Among all 30 analysed soil samples only 3 (10%) samples collected from Mangalwedha and Kacharewadi locations of Mangalvedha tehsils and Kandalgaon location of South Solapur tehsil found to be very low (< 140 kg ha^{-1}) and remaining all 27 samples (90%) were categorized under low (140-208 kg ha^{-1}) category of soil available nitrogen. The results of available nitrogen are accordance with Reshma *et al.* (2020) [13] and Ghodke *et al.* (2016) [7].

Further detailed study of available nitrogen in relation to soil texture was performed and observed that the fine textured class (clay, silty clay, silty clay loam and clay loam) of soils estimated on an average more (167.60 kg ha^{-1}) available nitrogen as compared to medium (163.53 kg ha^{-1}) and course (143.41 kg ha^{-1}) textured classes of soils. This variation can be attributed to the ability of fine textured soils to accumulate organic matter and nitrogen compounds due to their slow drainage properties. The combination of a higher cation exchange capacity (CEC), increased surface area, improved moisture retention and slower drainage in fine textured soils collectively contribute to the retention, mineralization and availability of nitrogen, resulting in its higher abundance compared to soils with other textures.

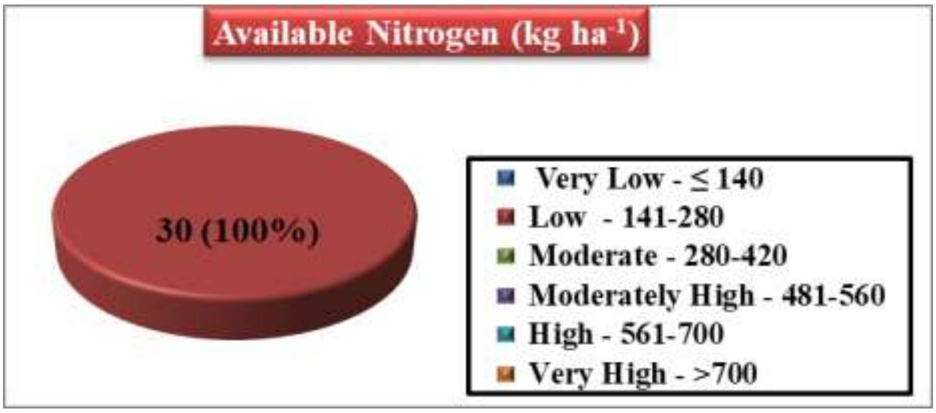

Fig 5: Available Nitrogen (kg ha^{-1})

3.2.4.2 Soil Available Phosphorus

The presented data in Table 2 pertaining to soil phosphorus showed that the concentration of available of phosphorus in the soils of Solapur district varied from 3.9 to 16.3 kg ha^{-1} and having average value of 9.3 kg ha^{-1}. From collected all soil samples of Solapur district the lower (3.9 kg ha^{-1}) available phosphorus content was recorded in Kandalgaon village of South Solapur tehsil and higher (16.3 kg ha^{-1}) available phosphorus content was recorded in Mohal (KVK) village locations of Mohal tehsil of Solapur district.

Out of all collected soil samples from Solapur district about, 7 samples (23.33%), 21 samples (70.0%) and 2 samples (6.67%) were grouped in very low, low and moderate class of soil available phosphorus, respectively. The results pertaining to available Phosphorus in soils confirmed by Reshma *et al.* (2020) [13] and Ghodke *et al.* (2016) [7].

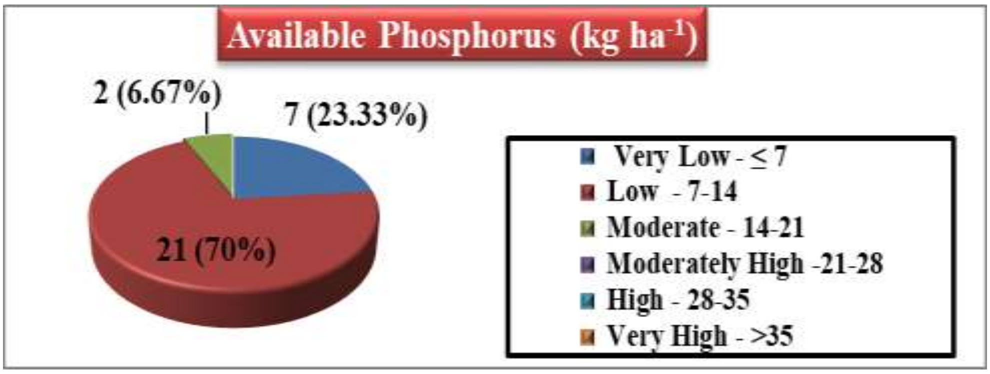

Fig 6: Available Phosphorus (kg ha^{-1})

3.2.4.3 Soil Available Potassium

The analysed data pertaining to soil available potassium displayed in Table 2. According to data it is cleared that the available potassium in collected soil samples of Solapur district varied from 235.2 to 571.2 kg ha^{-1} with the mean value of 392.4 kg ha^{-1}. The soil sample collected from Kacharewadi village in Mangalvedha tehsil recorded lowest (235.2 kg ha^{-1}) status of available potassium and highest (672.0 kg ha^{-1}) status of available potassium was recorded from Bhosare village in Mhada tehsil of Solapur district. Out of all 30 soil samples of Solapur district at about 3 samples (10.0%), 1 sample (3.33%) and 26 samples (86.67%) samples were included in moderately high, high and very high availability class of soils available potassium. The very high concentration of potassium in soils might be due to type of potassium bearing parent material from which soils are formed or it could be due to presence of high montmorillonite clay minerals and unnecessary excess use of potassic fertilizers. The similar trend of observations in respect of soil available potassium was noted by Ghodke *et al.* (2016) [7].

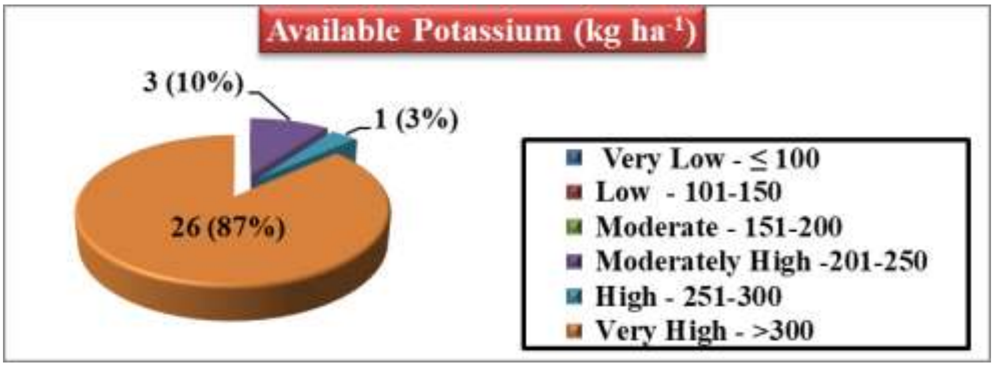

Fig 7: Available Potassium (kg ha^{-1})

Table 3: Organic Carbon and their Fractions in Soils of Solapur District

Sr. No.	Tehsil	Village	Soil OC ($g\ kg^{-1}$)	WSC ($mg\ kg^{-1}$)	SMBC Ec*2.64 ($mg\ kg^{-1}$)	POSC ($mg\ kg^{-1}$)	POMC ($g\ kg^{-1}$)	Humic Acid C ($g\ kg^{-1}$)	Fulvic Acid C ($g\ kg^{-1}$)	TOC ($g\ kg^{-1}$)
1	Pandharpur	Lakshmi Takli	3.75	3.14	198.94	533.25	1.27	127.94	73.53	6.60
2	Pandharpur	Sharadrenagar Takli (Pulses & Oilseed Rese. Cent.)	7.35	2.92	273.93	589.50	1.23	139.71	72.06	12.90
3	Mangalvedha	Dharamgaon	7.05	3.36	268.01	639.00	2.16	138.24	98.53	13.55
4	Mangalvedha	Mangalvedha	3.15	3.59	132.86	537.75	1.76	123.53	67.65	5.45
5	Mangalvedha	Tandor	7.20	3.14	204.51	652.50	1.42	133.82	117.65	11.30
6	South Solapur	Vadapur	7.50	5.61	274.64	510.75	2.33	116.18	108.82	10.30
7	North Solapur	Telgaon	5.70	3.59	271.98	609.75	1.72	94.12	70.59	12.35
8	North Solapur	Mulegaon (ZARS)	5.40	3.14	203.35	456.75	1.75	100.00	77.94	8.80
9	Mohal	Mohal KVK	5.40	3.14	268.16	470.25	1.84	110.29	79.41	8.95
10	Mhada	Madha Uplai Kh.	4.20	6.06	332.50	546.75	2.28	85.29	69.12	11.70
11	Karmala	Mangi	6.30	4.49	330.53	553.50	1.63	98.53	67.65	11.75
12	Mangalvedha	Anawali	7.20	3.59	270.70	501.75	2.00	102.94	48.53	11.40
13	Sangole	Bamani	7.05	3.36	274.33	605.25	1.33	130.88	75.00	11.75
14	Pandharpur	Khardi	4.35	6.06	203.46	510.75	2.04	111.76	42.65	8.40
15	North Solapur	Dongaon	8.10	5.83	329.55	497.25	2.12	133.82	85.29	15.30
16	North Solapur	Mulegaon (Div. Agril. Res. Cent.)	4.50	6.06	335.18	492.75	1.84	85.29	72.06	7.45
17	Mohal	Sawaleshwar	6.45	3.36	265.95	645.75	1.69	94.12	86.76	11.50
18	Malshiras	Mardi	8.25	3.81	205.89	603.00	2.37	91.18	76.47	14.92
19	Malshiras	Paniv	4.20	4.26	204.45	524.25	1.51	105.88	69.12	10.80
20	Sangole	Wani Chinchole	4.65	5.83	205.78	488.25	1.35	119.12	64.71	9.45
21	Sangole	Burange Wadi	3.30	3.14	201.61	497.25	1.64	104.41	64.71	5.65
22	Sangole	Jawala	8.25	3.36	201.44	654.75	1.63	130.88	67.65	14.70
23	Karmala	Phisare	8.25	5.83	197.42	591.75	1.72	107.35	72.06	18.45
24	Mohal	Waddegaon	7.95	3.14	268.09	571.50	1.56	114.71	98.53	12.60
25	Mohal	Kamti BK.	5.55	2.92	266.68	591.75	1.52	94.12	91.18	12.16
26	Malshiras	Malshiram (Khudus)	4.50	3.36	264.29	506.25	1.38	86.76	75.00	11.24
27	Mhada	Bhosare	3.90	4.26	200.58	328.50	1.78	101.47	85.29	7.95
28	Mangalvedha	Kacharewadi	3.30	4.49	134.09	315.00	1.80	101.94	75.73	5.85
29	Sangole	Lonavire	3.75	3.36	274.01	506.25	1.79	82.35	73.53	8.90
30	South Solapur	Kandalgaon	3.00	4.49	201.71	299.25	1.25	80.88	75.00	5.15
	Max		8.25	6.06	335.18	654.75	2.37	139.71	117.65	18.45
	Min		3.00	2.92	132.86	299.25	1.23	80.88	42.65	5.15
	Mean		5.65	4.09	242.15	527.70	1.72	108.25	76.74	10.58
	St. Dev.		1.78	1.11	53.95	91.69	0.32	17.82	15.38	3.22
	CV		31.52	27.13	22.3	17.38	18.57	16.46	20.05	30.42

Table 4: Correlation between Aggregate Stability (Mean Weight Diameter) and other Soil Properties Solapur District

	Soil OC	Avail. N	Avail. P	Avail. K	pH	EC	$CaCO_3$	BD	Humic Acid C	Fulvic Acid C	POMC	POSC	WSC	SMBC	TOC
Correlation	0.61*	0.42**	0.28	0.09	0.00	0.04	-0.21	-0.46**	0.39**	0.24	0.47*	0.55*	0.18	0.56*	0.52*
** : R table @ 5% * : R table @ 1%															

3.2.5 Soil Organic Carbon

The findings of soil organic carbon and its various pools of collected all soils samples of Solapur district are presented in Table 3. The data revealed that the soil organic carbon content varied from 3.0 $g\ kg^{-1}$ to 8.3 $g\ kg^{-1}$ with the mean value of 5.7 $g\ kg^{-1}$. Among collected all 30 soil samples, the minimum (3.0 $g\ kg^{-1}$) soil organic carbon were noted at Kandalgaon village location of South Solapur and the maximum (8.25 $g\ kg^{-1}$) soil organic carbon were noted in Mardi, Jawala and Phisare village locations of Malshiras, Sangola and Karmala Tehsils, respectively.

Out of all collected samples of Solapur district, total 7 samples (23.33%) collected from Laksmi Takli location of Pandharpur tehsil, Mangalvedha and Kacharewadi locations of Mangalvedha tehsil, Burangewadi and Lonavire locations of Sangole tehsil as well as Bhosare and Kandalgaon locations of South solapur tehsil found to be low in organic carbon content. About 10 samples (33.33%) collected from Telgaon, Mulegaon (ZARS), Mulegaon (Div. Agril. Res. Cent.) locations of North Solapur, Mohal KVK and Kamti Bk. locations of Mohal tehsil as well as Mhadha Uplain Kh, Khardi, and Wani Chinchole locations of Mhada, Pandharpur and Malshiras tehsils along with Paniv and Malshiram (Khudus) locations of Malshiras tehsil found to be moderate in soil organic carbon content, respectively. About 9 samples (30.0%) collected from Sharadnagar Takli (PORC), Vadapur, Mangi and Bamani locations of Pandharpur, South Solapur, Karmala, and Sangole tehsils as well as Dhharamgaon, Tandor and Anawali locations of Mangalvedha tehsil and Sawaleshwar and Waddegaon locations of Mohal tehsil found to be moderately high in organic carbon content. Whereas, about 4 samples (13.33%) fetched from Dongaon, Mardi, Jawala and Phisare locations of North Solapur, Malshiras, Sangole and Karmala tehsils respectively found to be high in soil organic carbon, respectively.

Furthermore detailed investigation of data of soil organic carbon content in relation to soil texture was performed. The study observed that the among the various textured soils, fine textured class (including clay, silty clay, silty clay loam and clay loam) exhibited the highest average organic carbon content of 5.95 g kg^{-1}. The medium textured class (loam to sandy clay loam) of soils observed an average organic carbon content of 5.79 g kg^{-1}. In contrast, the coarser textured class of soils (sandy loam to sandy) estimated the lowest organic carbon content of 3.35 g kg^{-1}.

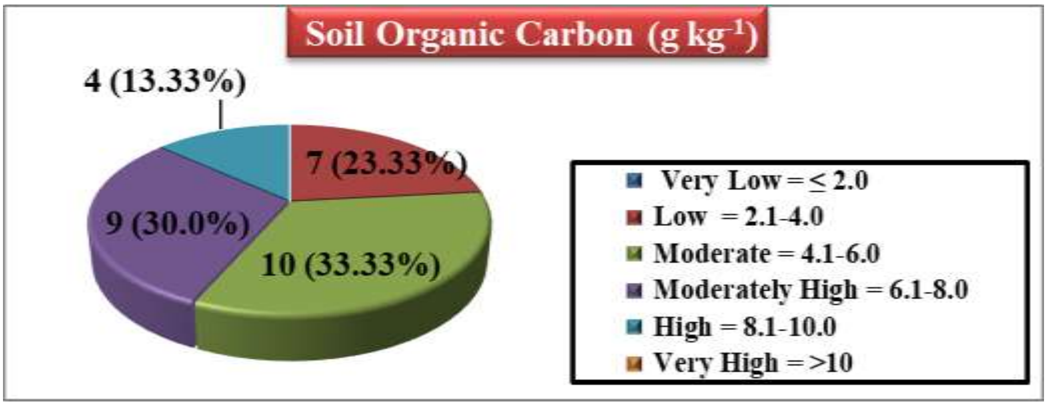

Fig 8: Soil Organic Carbon (g kg^{-1} Soil)

3.2.5.1 Soil Organic Carbon Fractions

The findings pertaining to various organic carbon pools of soils of Solapur district are presented in Table 3. The analysed data recognised that the Water Soluble Carbon (WSC) Soil Microbial Biomass Carbon (SMBC), Permanganate Oxidisable Soil Carbon (POSC), Particulate Organic Matter Carbon (POMC), Humic Acid Carbon, Fulvic Acid Carbon and Total Organic Carbon (TOC) were ranged from 2.92 to 6.06 mg kg^{-1} (mean 4.09), 132.86 to 335.18 mg kg^{-1} (mean 242.15), 299.5 to 654.25 mg kg^{-1} (mean 527.70), 1.23 to 2.37 g kg^{-1} (mean 1.72), 80.88 to 139.71 g kg^{-1} (mean 108.25), 42.65 to 117.65 g kg^{-1} (mean 76.74) and 5.15 to 18.45 g kg^{-1} (mean 10.58), respectively.

3.2.6 Correlation Studies of Aggregate Stability (MWD) with Physical and Chemical Properties of Soils of Solapur District

The statistical data pertaining to correlation studies between aggregate stability (MWD) with different soil parameters are presented in Table 4. The data showed the linear relationship between aggregate stability (MWD) with soil organic carbon and soil available nitrogen. Specifically, aggregate stability (MWD) found positively correlated with Particulate Organic Matter Carbon (POMC) ($r = 0.47^{*}$), Total Organic Carbon ($r = 0.52^{*}$), Permanganate Oxidisable Soil Carbon (POSC) ($r = 0.55^{*}$), Soil Microbial Biomass Carbon (SMBC) ($r = 0.56^{*}$) and Soil Organic Carbon (SOC) ($r = 0.61^{*}$) @ 1% level of significance. Similarly aggregate stability (MWD) also showed linear positive correlation with available nitrogen ($r = 0.42^{**}$) and humic acid carbon ($r = 0.39^{**}$) @ 5% level of significance respectively. Meanwhile, the aggregate stability (MWD) of soils of Solapur district recognized negatively correlated with electrical conductivity of soils ($r = -0.46^{**}$) @ 5% level of significance. The similar results of correlation studies also recognized by Guo *et al.* (2019) [8].

4. Conclusion

The soils within Solapur district exhibited significant variations in terms of colour and texture. The majority of soil samples, approximately 56.67% displayed poor aggregate stability, with the lowest stability observed in Kandalgaon village within the South Solapur tehsil, while only 43.33% of the samples exhibited good aggregate stability. The pH levels in the studied area ranged from neutral to alkaline and the soils were non-saline in nature. Moreover, roughly 66.67% of the samples displayed moderately high calcium carbonate content. The soils within the sampled district were characterized by low available nitrogen and phosphorus, but a high content of available potassium. The aggregate stability (MWD) of the soil samples reported positive correlation with soil organic carbon, particulate organic matter carbon, permanganate oxidizable soil carbon, soil microbial biomass carbon and total organic carbon @ 1% and with soil available nitrogen and humic acid carbon @ 5% level of significance. Conversely, soil aggregate stability (MWD) was negatively correlated with soil bulk density of soil @ 5% level of significance.

5. References

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