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Aggregate stability in soils of Nandurbar district and their interaction with available nitrogen and soil organic carbon

DD Fulpagare, NJ Ranshur, SR Patil and Ritu S Thakare

Abstract
An survey entitled "Studies on aggregate stability in soils of Nandurbar District and their correlation with available nitrogen and soil organic carbon" was conducted between 2019 to 2022. Total 21 soil samples were collected from 0-15 cm depth and exact locations of samples site was recorded by GPS device. The results indicated that about 17 samples (80.95%) reported low aggregate stability (MWD) and only 4 samples (19.05%) reported good aggregate stability. While the bulk density of soil ranged from 1.27-1.50 Mg m^{-3}. The organic carbon content, available N, P and K ranged between (2.5-9.4 g kg^{-1} soil), (145.5-215.9 kg ha^{-1}), (8.2-22.4 kg ha^{-1}) and (302.4-672.0 kg ha^{-1}), respectively. Whereas, 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 2.24 to 6.28 mg kg^{-1}, 138.52 to 440.87 mg kg^{-1}, 432.00 to 614.25 mg kg^{-1}, 1.42 to 2.93 g kg^{-1}, 80.5 to 163.9 g kg^{-1}, 61.5 to 133.2 g kg^{-1} and 4.45 to 23.35 g kg^{-1}, respectively.

Keywords: Aggregate stability, Mean Weight Diameter (MWD), aggregate stability

Introduction

Soil commonly called as earth or dirt or is a complex mixture of organic matter, minerals, gases, liquids and organisms which together support life on earth. However, the soil scientists, geologists, engineers and economists may use different terms for soil, such as soil, fragmented rock, earth and land, respectively (Das, 2015) [7]. Functionally, soil is the reservoir for water and nutrients, a water filtration medium, a decomposer of organic and toxic waste, an active component in the carbon cycle, and other things. Along with this soil carries considerable competencies that include ground water recharge, soil aeration, supply nutrients to plants, and provides room for microbial habitat and plenty of other activities that make soil an integral part of our life (Deshmukh, 2012) [8]. The Western Maharashtra is the central part of Maharashtra elongated from North to South end of state and it comprises ten districts *viz*; Kolhapur, Sangli, Satara, Solapur, Pune, Ahmednagar, Nashik, Jalgaon, Dhule and Nandurbar. Geographically Western Maharashtra comprises total 89,853 Sq.km area of the state and has hot and dry climates however it receives about 608-635 mm average rainfall (Aparajit, 2012) [1]. The vegetation cover also differ from area to area due to variations in topography, soils and climate, (Deshmukh, 2012) [8]. Majority soils of Western Maharashtra are found to be slightly alkaline in nature. The black cotton soils are found in Western Maharashtra are deep black to brown in colour and the soils of valleys are alluvial in nature (Bhattacharyya, *et al*., 2013, and Ingle, *et al*., 2018) [4, 12].

Aggregate stability is one of the important indicators of soil quality and soil health, as it is influenced by soil physical, chemical and biological properties of soils (Doran *et al*., 1996) [9]. Under stable aggregated soils there will be appropriate proportion of soil macro (> 0.05 mm) and micro (< 0.05 mm) pores which are essential for movements of soil air, water, microbes, nutrients, organic matter and gaseous exchange (Nimmo, 2004) [16]. A well aerated soil with sufficient moisture is essential condition for healthy plant and soil microorganisms (Trivedi *et al*., 2018) [21]. The stable aggregated soils having higher water infiltration rate, more water holding capacity, well microbial growth, good nutrients availability and not susceptible for water ponding. However, compacted soil with few aggregates and restrained pore spaces have issued for nutrients and water availability (Cerda, 2000) [6]. Soil organic carbon storage and aggregate stability exhibit complex interaction (Feller, *et al*., 2001) [10].

Organic matter not only acts as a binding agent in aggregates formations in soil but also play additional roles in its stability. Similarly, aggregates not only store carbon but also protects it from decomposition or mineralization (Lal *et al*., 2003) [14], because it is less subjected to microbial, physiochemical and enzymatic degradation (Bajracharya *et al*., 1998) [3]. The most valuable source of organic carbon in soils are the organic matter that obtained from partial and fully decomposed plants and animal debris. According to time of persistence in soil aggregates, soil organic carbon can be divided in to three main types *viz.*, a) transient or labile carbon fraction (polysaccharides and carbohydrates of soil organic matter), b) temporary (fungal hyphae and plant roots) (Tisdall and Oades, 1982) and c) [4] persistent or stable carbon fraction (humic substances which are more resistant aromatic compounds that are associated with polyvalent metal cations and strongly adsorbed) (Amézketa, 1999) [2]. Among these three groups transient and persistent organic substances helps in stabilization of microaggregates (< 0.25 mm) where as temporary organic substances helps in stabilization of macroaggregates (> 0.25 mm) (Amézketa, 1999; Tisdall and Oades, 1982) [2, 4].

The detail systematic investigation on aggregate stability and its interactions with soil available nitrogen and soil organic carbon in respect of Nandurbar District of Western Maharashtra is necessary for improving soil aggregates stability and carbon stocks and nitrogen content of soils. The information related to the above topic is very meagre and hence the detail investigation on this research paper.

Material and Method

Study Area

The Nandurbar district is located in the north west side of Maharashtra state at 21°00'00"-22°00'30" N latitude and 73°31'00"-74°45'30" E longitude, having average elevation of 210 meters (688 feet). The district has 5034 sq. km. area that is distributed in six tehsils (Kasetiya, *et al.* 2022) [13].

Soil Characteristics

The large area of district is covered by Deccan traps except few strips of alluvial land on both sides of the Tapi River. The major soil types found in district are coarse shallow, medium deep and deep black. The forest and pasture land is one important feature of the Nandurbar district (CGWB (2021) [5].

Climate

The district has hot and dry climate with minimum and maximum temperature ranges between 15.8 °C and 40.7 °C. The district receives on an average 767-801 mm annual rainfall (Kasetiya, *et al*. 2022) [13].

Results and Discussion

Physical Properties of Soils of Nandurbar District

The data regarding to the physical properties of 21 soil samples collected from Nandurbar district are presented in Table 1.

Soil Colour

The data of soil colour of Nandurbar district is presented in Table 1. The data revealed that out of 21 soil samples, about 7 sample (33.33 per cent) collected from different villages *viz*., Khamgaon, Navle Kh., Ashta, Tishi, Nandurbar AC, and Vikharan (Khondamali) villages of Nandurbar tehsil and Ukalpani (Pratapur) village of Navapur tehsil found to be dark brown (i.e. 2 of 10 YR 3/3 and 5 of 7.5 YR 3/2) in colour. Another 7 samples (33.33 per cent) collected from Kalada, Karankheda and Thanepada villages of Nandurbar tehsil, Dongargaon, Sarankheda (Pusanad), Purushottam Nagar villages of Shahada tehsil and Kolda (Shahade) village of Navapur tehsil recorded very dark grayish brown (10 YR 3/2) in colour. The 2 soil samples (9.53 per cent) collected from Navapada and Navapur villages of Navapur tehsil reported very dark gray (10 YR 3/1) in colour. The 3 soil samples i.e. 14.29 per cent collected from Chinchpada village of Navapur tehsil and Vavad Akrale and Nandurbar AC villages of Nandurbar tehsil were found to be brown in colour (10 YR 4/3, 7.5 YR 5/2 and 10 YR 5/3). Whereas only one sample (4.76 per cent) of Nimboni village of Navapur tehsil and another one sample (4.76 per cent) of Prakasha (Damarkheda) village of Shahada tehsil recorded dark grayish brown (10 YR 4/2) and dark gray in colours (10 YR 4/1), respectively.

The dark brown to dark gray colour of the soils might be due to the presence of organic matter and different soil forming minerals. Soil organic matter causes the darkness of soil by decreasing the Munsell value and chroma of soil. Red and brown colours caused by oxidation are more common, yellow or red soil indicates the presence of oxidized ferric iron oxides.

The results are in accordance with Prasad *et al.* (1995) [18], Kasetiya *et al*. (2022) [13] and Ghodke *et al*. (2016) [11].

Soil Texture

The data of soil textural classes of Nandurbar district presented in Table- 1 revealed that out of 21 samples, about 2 (9.59%) samples collected from Khamgaon and Navle Kh. villages of Nandurbar tehsil reported clayey in texture. About 1 (4.76%) sample of silty clay and another 1 (4.76%) sample of silty clay loam texture were reported in Ashta and Kalada villages of Nandrbar tehsil, respectively. About 6 (28.57%) samples collected from different locations *viz*, Dongargaon village of Shahada tehsil, Navapada and Nimboni villages of Navapur tehsil, Tishi, Nandurbar AC and Karankheda villages of Nandurbar tehsil, recorded clay loam texture. About 7 (33.33%) samples collected from Sarankheda (Pusanad), Purushottam Nagar villages of Shahada tehsil, Navapur, Chinchpada and Ukalpani (Pratapur) villages of Navapur tehsil and Thanepada and Vikhran (Khondamali) villages of Nandurbar tehsil were found to be loamy in texture. About 1 (4.76%) sample collected from Kolda (Shahada) village of Navapur tehsil reported sandy clay and 3 (14.29%) samples collected from Prakasha (Damarkheda) village of Shahada tehsil and Vavad Akrale and Nandurbar AC villages of Nandurbar tehsil recorded sandy loam texture, respectively.

The textural variation in soils might be due to discrepancy in parent materials from which soils were formed.

The soil colour and textural observation are conformity with those reported by Ingle *et al*. (2018) [12] and Kasetiya *et al.* (2022) [13].

Table 1: Physical Properties of Soils of Nandurbar District

Sr. No	Tehsil	Village	Latitude	Longitude	Soil Colour	Soil Textural Class	MWD (mm)	BD (Mgm^{-3})
1	Nandurbar	Khamgaon	21°21'03.4"N	74°12'38.0"E	10 YR 3/3 (Dark Brown)	Clay	1.51	1.47
2	Nandurbar	Nalve Kh	21°22'37.3"N	74°13'03.7"E	7.5 YR 3/2 (Dark Brown)	Clay	1.06	1.47
3	Nandurbar	Ashta	21°16'16.3"N	74°13'07.0"E	10 YR 3/3 (Dark Brown)	Silty Clay	0.72	1.35
4	Nandurbar	Kalada	21°26'03.7"N	74°16'47.7"E	10 YR 3/2 (Very Dark Grayish Brown)	Silty Clay Loam	0.75	1.41
5	Shahada	Dongargaon	21°33'54.6"N	74°31'59.1"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay Loam	0.76	1.48
6	Navapur	Navapada	21°11'57.4"N	73°58'08.4"E	10 YR 3/1 (Very Dark Gray)	Clay Loam	1.35	1.43
7	Navapur	Nimboni	21°17'23.9"N	74°01'53.2"E	10 YR 4/2 (Dark Grayish Brown)	Clay Loam	1.49	1.27
8	Nandurbar	Tishi	21°23'30.7"N	74°21'28.1"E	7.5 YR 3/2 (Dark Brown)	Clay Loam	0.64	1.42
9	Nandurbar	Nandurbar AC	21°22'37.3"N	74°16'18.5"E	7.5 YR 3/2 (Dark Brown)	Clay Loam	0.98	1.50
10	Nandurbar	Karankheda	21°23'32.1"N	74°10'30.3"E	10 YR 3/2 (Very Dark Grayish Brown)	Clay Loam	0.72	1.46
11	Shahada	Sarankheda (Pusanad)	21°26'39.9"N	74°31'01.7"E	10 YR 3/2 (Very Dark Grayish Brown)	Loam	0.66	1.42
12	Shahada	Purushottam Nagar	21°34'15.1"N	74°30'16.0"E	10 YR 3/2 (Very Dark Grayish Brown)	Loam	0.64	1.31
13	Navapur	Navapur	21°10'28.4"N	73°47'36.6"E	10 YR 3/1 (Very Dark Gray)	Loam	0.85	1.33
14	Navapur	Chinchpada	21°10'46.6"N	73°53'48.5"E	10 YR 4/3 (Brown)	Loam	0.85	1.39
15	Nandurbar	Thanepada	21°15'14.5"N	74°15'35.1"E	10 YR 3/2 (Very Dark Grayish Brown)	Loam	0.82	1.50
16	Navapur	Ukalpani (Pratapur)	21°02'12.8"N	73°50'31.3"E	7.5 YR 3/2 (Dark Brown)	Loam	0.92	1.40
17	Nandurbar	Vikharan (Khondamali)	21°26'08.8"N	74°20'55.8"E	7.5 YR 3/2 (Dark Brown)	Loam	0.64	1.47
18	Navapur	Kolda (Shahade)	21°27'02.8"N	74°17'20.3"E	10 YR 3/2 (Very Dark Grayish Brown)	Sandy Clay	0.49	1.45
19	Shahada	Prakasha (Damarkheda)	21°30'51.1"N	74°22'47.0"E	10 YR 4/1 (Dark Gray)	Sandy Loam	0.50	1.35
20	Nandurbar	Vavad Akrale	21°21'09.4"N	74°19'59.2"E	7.5 YR 5/2 (Brown)	Sandy Loam	0.19	1.46
21	Nandurbar	Nandurbar AC	21°21'37.7"N	74°16'09.8"E	10 YR 5/3 (Brown)	Sandy Loam	0.46	1.44
	Max						1.51	1.50
	Min						0.19	1.27
	MEAN						0.81	1.42
	STDEV						0.33	0.06
	CV						40.76	4.52

Soil Aggregate Stability (Mean Weight Diameter)

The data of aggregate stability (MWD) of soils of Nandurbar district displayed in Table-1 implicited that the aggregate stability (MWD) of soils of Nandurbar district ranged from 0.19-1.51 mm with mean of 0.81 mm. Among all collected soil samples the lowest (0.19 mm) and highest (1.51 mm) aggregate stability (MWD) were recorded in Vavad Akral and Khamgaon villages of Nandurbar tehsil, respectively.

Out of all 21 collected soil samples about 17 samples i.e. 80.95% recorded MWD < 1 mm which indicate poor aggregate stability and 4 samples i.e. 19.05% recorded MWD > 1 mm which indicate good aggregate stability.

The poor aggregate stability of the soils might be due to less availability of cementing agents, especially organic matter due to irregular application of organic manures (FYM, compost, and crop residue), hot and dry climate and frequent tillage practices fasten the rate of decomposition of available organic matter.

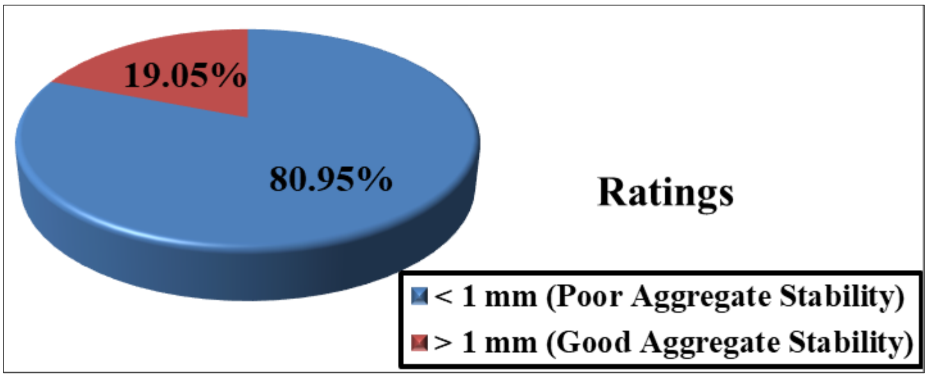

Fig 1: Soil Aggregate Stability (MWD)

Bulk Density of Soil

The analysed data about bulk density of all 21 soil samples collected from Nandurbar districts was presented in Table 1 revealed that the bulk density ranged from 1.27-1.50 Mg m^{-3} with the mean of 1.42 Mg m^{-3}. Out of all samples of Nandurbar district the lowest (1.27 Mg m^{-3}) and highest (1.50

Mg m^{-3}) bulk density of soil was recorded in Nimboni and Thanepada villages of Navapur and Nandurbar tehsils, respectively.

The readings of bulk density found quite high, might be due to presence of heavy clay minerals, low organic matter, history of compaction by heavy machineries and monocroping of rice in some west part of district etc.

The findings of soil bulk density resembled with those recorded by Ingle *et al*. (2018) [12] and Ghodke *et al*. (2016) [11].

Chemical Properties of Soils of Nandurbar District-
Soil pH

The analysed data regarding soil pH of all 21 collected soil samples of Nandurbar district was presented in Table- 2 and noted that the pH of soils of Nandurbar district ranged from 7.24-8.65 with the mean value of 7.98. The lowest pH (7.24) and highest pH (8.65) was recorded from two separate locations of Nandurbar AC. Among analysed all 21 soil samples, about 2 samples i.e. 9.52% found to be neutral and about 19 samples i.e. 90.48% found to be alkaline in nature.

The dominance of alkaline range of soil pH was might be due to the types of parental material (basaltic), saturation of bases, low amount of rainfall, changes in land use pattern and frequent use of basic chemical fertilizers.

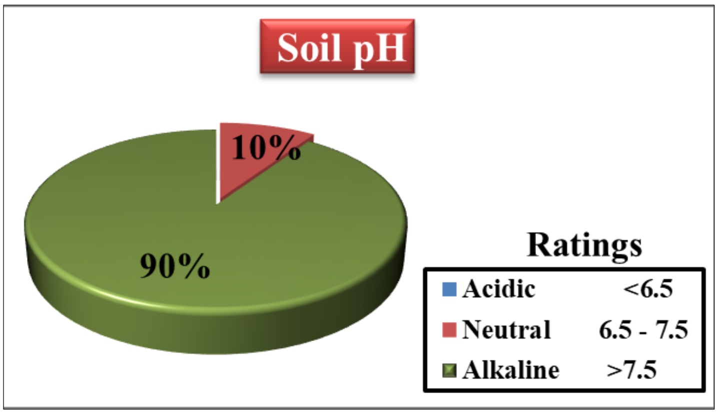

Fig 2: Soil pH

Soil EC

The data presented in Table- 2 pertaining to electric conductivity (EC) disclosed that the electric conductivity of collected soil sample from Nandurbar district ranged from 0.13 to

0.41 dS m^{-1} with the mean of 0.20 dS m^{-1}. Among all 21 soil samples the lowest (0.13 dS m^{-1}) and highest (0.41 dS m^{-1}) electric conductivity were recorded in Navapada village of Navapur tehsil and Vavad Akrale village of Nandurbar tehsil, respectively.

The findings indicated that the soils of Nandurbar district are safe with respect to electric conductivity. About all 21 i.e. 100% samples had electric conductivity less than 1 dS m^{-1} and hence, all samples belong to non-saline or normal soil category.

The observation of soil pH and EC are accordance with Prasad *et al*. (1995) [18], Ingle *et al*. (2018) [12] and Ghodke *et al*. (2016) [11].

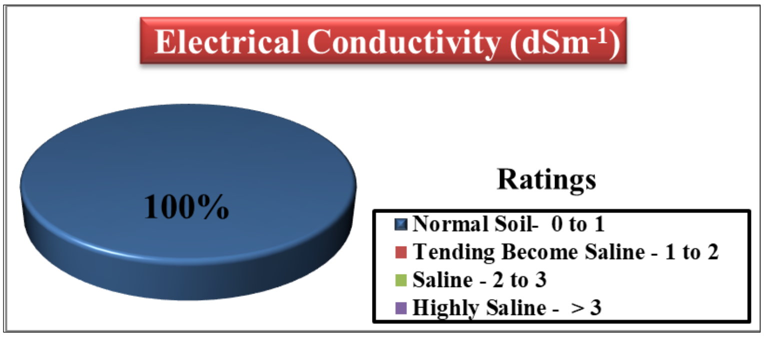

Fig 3: Electrical Conductivity (dSm^{-1})

Calcium Carbonate (%)

The data of calcium carbonate content in the soils of Nandurbar district depicted in Table- 2. The data revealed that the concentration of $CaCO_3$ varied from 0.63 to 6.75% with an average value of 2.25%. Among all samples of Nandurbar district the $CaCO_3$ content recorded lowest (0.63%) and highest (6.75%) in Navapada and Nandurbar villages of Navapur and Nandurbar tehsils, respectively.

Out of 21 samples collected from various locations of Nandurbar district, about 3 samples i.e. 14.28%, 7 samples i.e. 33.33%, 10 samples i.e 47.62% and 1 sample i.e. 4.76% were categorised in low, moderate, moderately high and high categories, respectively.

The ranges of CaCO3 content are in accordance with Parhad *et al*. (2018) [17] reported in studies of soils of Dhule district.

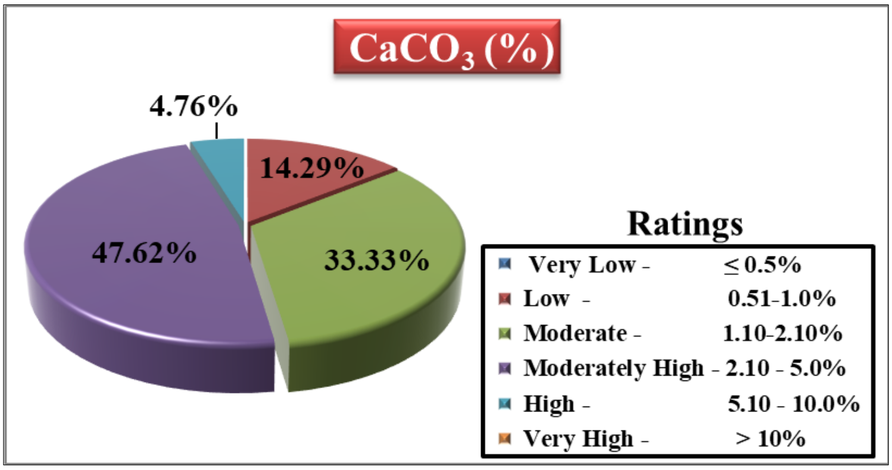

Fig 4: $CaCO_3$ (%)

Soil Available Nitrogen, Phosphorus and Potassium

The data of available nitrogen, phosphorus and potassium of collected soil samples of Nandurbar district was presented in Table- 2

Available Nitrogen

The data presented in Table- 2 revealed that the available nitrogen content of soil samples collected from 21 different locations of Nandurbar district ranged from 145.5 to 215.9 kg ha^{-1} with the average value of 173.1 kg ha^{-1}. The lowest (145.5 kg ha^{-1}) and highest (215.9 kg ha^{-1}) value of available nitrogen content was recorded in Nandurbar AC and Nimboni villages of Nandurbar and Navapur tehsils, respectively.

About all 21 (100%) soil samples falls under low category of soil available nitrogen. The standard deviation (SD) and cumulative variance (CV) for the 21 soil samples was about 20.2 and 11.7 that indicates not much variation in available nitrogen status in soils of Nandurbar district.

Continues intensive monocropping, frequent tillage operation, leaching and volatilization losses, and soil erosion might be some important reasons of low status of nitrogen.

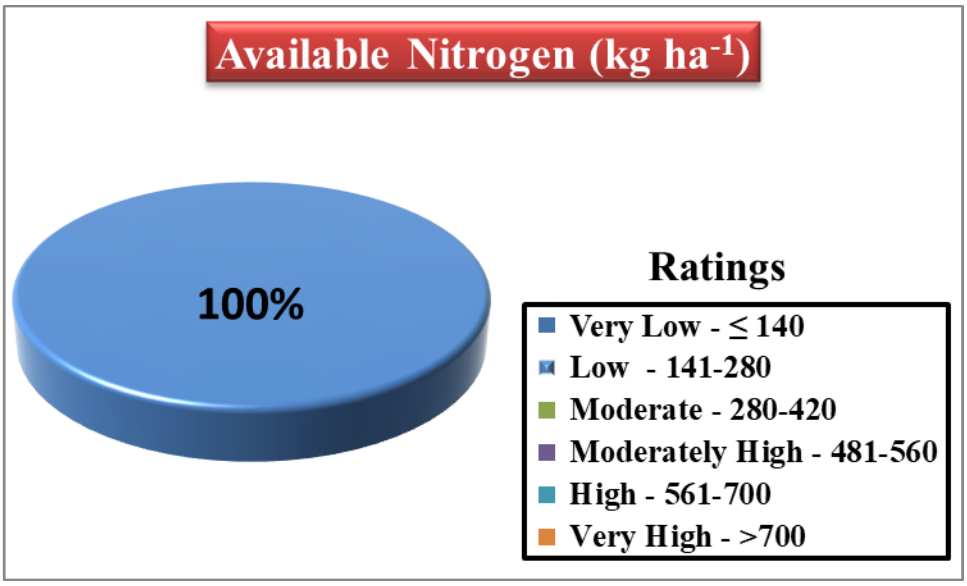

Fig 5: Available Nitrogen (kg ha^{-1})

Table 2: Chemical Properties of Soils of Nandurbar District

Sr. No.	Tehsil	Village	Latitude	Longitude	pH	EC (dSm^{-1})	$CaCO_3$ (%)	Avail. N (Kg ha^{-1})	Avail. P (Kg ha^{-1})	Avail. K (Kg ha^{-1})
1	Nandurbar	Khamgaon	21°21'03.4"N	74°12'38.0"E	8.25	0.19	3.13	203.1	16.0	336.0
2	Nandurbar	Nalve Kh	21°22'37.3"N	74°13'03.7"E	7.70	0.15	2.13	187.1	16.6	548.8
3	Nandurbar	Ashta	21°16'16.3"N	74°13'07.0"E	8.20	0.17	2.63	196.7	8.2	548.8
4	Nandurbar	Kalada	21°26'03.7"N	74°16'47.7"E	8.19	0.18	2.50	187.1	16.9	313.6
5	Shahada	Dongargaon	21°33'54.6"N	74°31'59.1"E	8.35	0.14	1.38	158.3	22.1	672.0
6	Navapur	Navapada	21°11'57.4"N	73°58'08.4"E	8.32	0.13	0.63	164.7	21.4	660.8
7	Navapur	Nimboni	21°17'23.9"N	74°01'53.2"E	7.95	0.21	2.88	215.9	16.9	459.2
8	Nandurbar	Tishi	21°23'30.7"N	74°21'28.1"E	7.78	0.16	3.63	183.9	14.9	526.4
9	Nandurbar	Nandurbar AC	21°22'37.3"N	74°16'18.5"E	7.24	0.17	6.75	171.1	8.9	414.4
10	Nandurbar	Karankheda	21°23'32.1"N	74°10'30.3"E	8.11	0.27	1.88	199.9	11.4	504.0
11	Shahada	Sarankheda (Pusanad)	21°26'39.9"N	74°31'01.7"E	8.21	0.17	1.13	151.9	20.9	638.4
12	Shahada	Purushottam Nagar	21°34'15.1"N	74°30'16.0"E	8.23	0.24	1.25	155.1	16.6	436.8

13	Navapur	Navapur	21°10'28.4"N	73°47'36.6"E	7.55	0.15	1.25	151.9	22.4	649.6
14	Navapur	Chinchpada	21°10'46.6"N	73°53'48.5"E	7.83	0.19	1.00	158.3	14.5	436.8
15	Nandurbar	Thanepada	21°15'14.5"N	74°15'35.1"E	7.50	0.25	2.63	187.1	12.6	515.2
16	Navapur	Ukalpani (Pratapur)	21°02'12.8"N	73°50'31.3"E	7.70	0.19	0.75	161.5	20.0	638.4
17	Nandurbar	Vikharan (Khondamali	21°26'08.8"N	74°20'55.8"E	8.09	0.28	3.63	151.9	14.2	504.0
18	Navapur	Kolda (Shahade)	21°27'02.8"N	74°17'20.3"E	7.64	0.18	1.13	155.1	22.0	660.8
19	Shahada	Prakasha (Damarkheda)	21°30'51.1"N	74°22'47.0"E	8.28	0.29	2.50	167.9	17.1	403.2
20	Nandurbar	Vavad Akrale	21°21'09.4"N	74°19'59.2"E	7.89	0.41	2.50	180.7	13.0	302.4
21	Nandurbar	Nandurbar AC	21°21'37.7"N	74°16'09.8"E	8.65	0.18	2.00	145.5	11.2	324.8
Max					8.65	0.41	6.75	215.9	22.4	672.0
Min					7.24	0.13	0.63	145.5	8.2	302.4
MEAN					7.98	0.20	2.25	173.1	16.1	499.7
STDEV					0.35	0.07	1.37	20.2	4.3	123.6
CV					4.35	32.12	60.96	11.7	26.7	24.7

Available Phosphorus

The data depicted in Table- 2 indicated that the available phosphorus content in the soils of Nandurbar district varied from 8.2 to 22.4 kg ha^{-1} with the mean of 16.1 kg ha^{-1}. Among all collected soil samples the available phosphorus content recorded lowest (8.2 kg ha^{-1}) and highest (22.4 kg ha^{-1}) in Ashta and Navapur villages of Nandurbar and Navapur tehsils, respectively.

Out of 21 soil samples, about 6 samples (28.57%), 11 samples (52.38%) and 4 samples (19.05%) were found to be low, moderate and moderately high categories of soil available phosphorus, respectively.

The low to moderately low status of phosphorus might be due to alkaline soil pH, least availability of organic and inorganic phosphorus in soils. However, the presence of phosphorus fixing elements such as calcium, magnesium, aluminium and iron that fixes available phosphorus in soil and thereby making it unavailable to the plants.

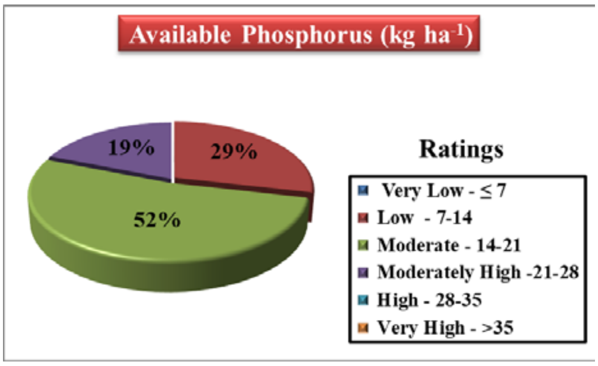

Fig 6: Available Phosphorus (kg ha^{-1})

Available Potassium

The analysed data pertaining to soil available potassium of collected soil samples from Nandurbar district was depicted in Table- 2. The data showed that the available potassium of collected soil samples ranged from 302.4 to 672.0 kg ha^{-1} with the mean value of 499.7 kg ha^{-1}. Whereas, the lowest available potassium (302.4 kg ha^{-1}) was reported in soil sample collected from Vavad Akrale village of Nandurbar tehsil and highest (672.0 kg ha^{-1}) available potassium was recorded in Dongargaon village of Shahada tehsil of Nandurbar district, respectively. All 21 i.e 100% samples were found to be very high in availability potassium. The presence of very high concentration of available potassium in soils might be due to type of potassium bearing parent material (orthoclase and muscovite) from which soil are formed or it could be due to presence of high montmorillonite clay minerals and unscintific use of potassic fertilizers.

The results of soil available nitrogen, phosphorus and potassium are in the line of Ghodke *et al*. (2016) [11], Ingle, *et al*. (2018) [12].

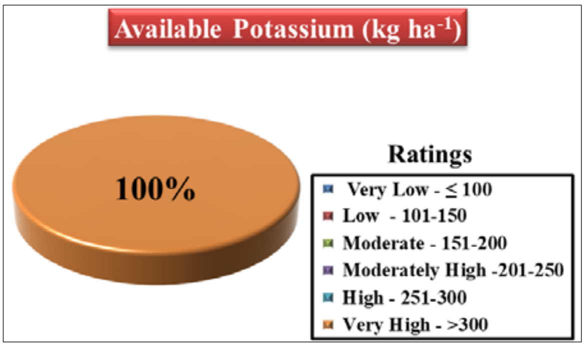

Fig 7: Available Potassium (kg ha^{-1})

Soil Organic Carbon

The data concerning about soil organic carbon and their different fractions in soils of Nandurbar district were depicted in Table- 3 The data in respect of organic carbon content in soil samples of Nandurbar district ranged from 2.5 to 9.4 g kg^{-1} with mean value of 5.3 g kg^{-1}. Among all collected soil samples the lowest (2.5 g kg^{-1}) and highest (9.4 g kg^{-1}) organic carbon content has been recorded in Vavad Akrale and Ukalpani (Pratapur) villages of Nandurbar and Navapur tehsil of Nandurbar district, respectively.

Out of all soil samples of Nandurbar district, about 7 samples (33.33%) were found to be low, 7 samples (33.33%) were moderate, 4 samples (19.05%) were moderately high and 3 samples (14.29%) were high in soil organic carbon content.

The low to moderately high status of soil organic carbon might be due to least availability and irregular application of organic manures (FYM, Compost, and Vemicompost), less retention of crop residues, frequent tillage operations and hot and dry climate fasten the rate of decomposition of available soil organic matter.

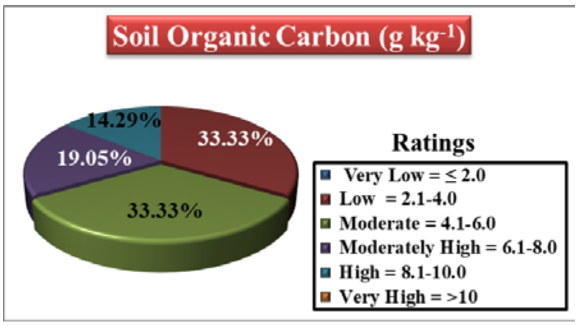

Fig 8: Soil Organic Carbon (g kg^{-1})

Soil Organic Carbon Fractions

The assessed data pertaining different soil carbon fractions presented in Table- 3 The data revealed 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 2.24 to 6.28 mg kg^{-1} (mean 4.46), 138.52 to 440.87 mg kg^{-1} (mean 261.81),
432.00 to 614.25 mg kg^{-1} (mean 514.61), 1.42 to 2.93 g kg^{-1} (mean 1.72), 80.5 to 163.9 g kg^{-1}
(mean 121.7), 61.5 to 133.2 g kg^{-1} (mean 98.0) and 4.45 to 23.35 g kg^{-1} (mean 11.24), respectively.

Correlation Studies of Aggregate Stability (Mean Weight Diameter) with Physical and Chemical Properties of Soils

The data of correlation studies of analysed soil properties was depicted in Table- 4. The data disclosed that the soil aggregate stability (MWD) positively correlated with soil Available Nitrogen ($r = 0.46^{**}$), Soil Organic Carbon ($r = 0.52^{**}$), Particulate Organic Matter Carbon ($r = 0.52^{**}$) and Permanganate Oxidisable Soil Carbon ($r = 0.52^{**}$) @ 5% level of significance and with Humic Acid Carbon ($r = 0.55^{*}$) and Total Organic Carbon ($r = 0.62^{*}$) @ 1% level of significance. However, soil aggregate stability (MWD) also found negatively correlated with electric conductivity of soil ($r = 0.49^{**}$) @ 5% level of significance.
The results of correlations studies are confirmatory with those reported by Mandal *et al*. (2017) [15] and Sarker *et al*. (2018) [19].

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

Sr. No	Tehsil	Village	Latitude	Longitude	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	Nandurbar	Khamgaon	21°21'03.4"N	74°12'38.0"E	4.88	4.71	289.01	537.75	1.77	131.7	109.8	10.25
2	Nandurbar	Nalve Kh	21°22'37.3"N	74°13'03.7"E	6.38	6.28	147.33	540.00	1.59	121.5	61.5	18.65
3	Nandurbar	Ashta	21°16'16.3"N	74°13'07.0"E	8.78	4.93	425.64	596.25	2.02	103.9	112.7	16.45
4	Nandurbar	Kalada	21°26'03.7"N	74°16'47.7"E	3.83	4.49	438.55	519.75	1.62	125.9	93.7	7.00
5	Shahada	Dongargaon	21°33'54.6"N	74°31'59.1"E	5.18	4.04	140.54	506.25	1.42	134.6	112.7	9.95
6	Navapur	Navapada	21°11'57.4"N	73°58'08.4"E	6.08	4.71	366.87	546.75	1.83	143.4	124.4	17.25
7	Navapur	Nimboni	21°17'23.9"N	74°01'53.2"E	9.08	4.49	440.87	612.00	2.93	147.8	133.2	23.35
8	Nandurbar	Tishi	21°23'30.7"N	74°21'28.1"E	2.93	4.26	356.44	436.50	1.59	99.5	77.6	6.05
9	Nandurbar	Nandurbar AC	21°22'37.3"N	74°16'18.5"E	5.78	6.06	152.80	506.25	1.49	114.1	95.1	14.30
10	Nandurbar	Karankheda	21°23'32.1"N	74°10'30.3"E	5.48	4.26	219.28	479.25	1.53	111.2	80.5	11.75
11	Shahada	Sarankheda (Pusanad)	21°26'39.9"N	74°31'01.7"E	4.13	4.26	138.52	495.00	1.46	143.4	109.8	8.65
12	Shahada	Purushottam Nagar	21°34'15.1"N	74°30'16.0"E	6.38	4.93	152.73	614.25	1.75	163.9	106.8	14.50
13	Navapur	Navapur	21°10'28.4"N	73°47'36.6"E	4.43	4.26	207.72	501.75	1.47	120.0	95.1	8.50
14	Navapur	Chinchpada	21°10'46.6"N	73°53'48.5"E	4.73	2.24	431.73	438.75	1.60	102.4	70.2	7.60
15	Nandurbar	Thanepada	21°15'14.5"N	74°15'35.1"E	3.38	4.49	144.21	488.25	1.57	137.6	121.5	4.45
16	Navapur	Ukalpani (Pratapur)	21°02'12.8"N	73°50'31.3"E	9.38	4.93	414.82	612.00	2.49	140.5	102.4	20.70
17	Nandurbar	Vikharan (Khondamali	21°26'08.8"N	74°20'55.8"E	6.23	4.26	368.78	515.25	1.91	115.6	83.4	12.05
18	Navapur	Kolda (Shahade)	21°27'02.8"N	74°17'20.3"E	3.83	5.16	144.21	479.25	1.62	102.4	111.2	7.05
19	Shahada	Prakasha (Damarkheda)	21°30'51.1"N	74°22'47.0"E	3.08	4.71	219.91	470.25	1.57	109.8	99.5	5.00
20	Nandurbar	Vavad Akrale	21°21'09.4"N	74°19'59.2"E	2.48	4.04	146.08	432.00	1.42	80.5	76.1	5.40
21	Nandurbar	Nandurbar AC	21°21'37.7"N	74°16'09.8"E	3.98	2.24	151.99	479.25	1.56	106.8	80.5	7.20
Max					9.38	6.28	440.87	614.25	2.93	163.9	133.2	23.35
Min					2.48	2.24	138.52	432.00	1.42	80.5	61.5	4.45
MEAN					5.25	4.46	261.81	514.61	1.72	121.7	98.0	11.24
STDEV					1.97	0.94	122.68	56.39	0.37	20.1	19.1	5.49
CV					37.58	21.01	46.86	10.96	21.48	16.5	19.5	48.85

Table 4: Correlation Between Aggregate Stability (Mean Weight Diameter) and Other Soil Properties of Nandurbar 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	0.52^{**}	0.46^{**}	0.16	0.13	-0.08	-0.49^{**}	0.09	-0.12	0.55^{*}	0.42	0.52^{**}	0.52^{**}	0.28	0.39	0.62^{*}
R Calculated	2.65	2.28	0.73	0.56	-0.36	-2.42	0.37	-0.53	2.86	2.04	2.64	2.68	1.29	1.87	3.46
R table 5%**	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
R table 1%*	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86

Conclusion

From the study, it can be concluded that, the soils of Nandurbar districts exhibited morphological differences and reported poor aggregate stability. The soil samples in the studied area had a neutral to alkaline pH, were non-saline, and exhibited a wide range of calcium carbonate content ranging from very low to high. Whereas, the soils are low in available nitrogen, low to moderately high in available phosphorus and very high in available potassium and organic carbon content ranged from low to high range. The aggregate stability (MWD) of the soil samples showed positive correlations with soil available nitrogen, soil organic carbon, particulate organic matter carbon, and permanganate oxidizable soil carbon at a 5% level of significance. Furthermore, significant positive correlations were observed with humic acid carbon and total organic carbon at a 1% level of significance. However, soil aggregate stability (MWD) was found to be negatively correlated with soil electric conductivity at a 5% level of significance.

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