Research Article

Soil Carbon Status as Influenced by Irrigated and Rainfed Cotton Crops and Their Correlation with Important Soil Chemical Properties

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Abstract

The present investigation was carried out with an objective to status of soil carbon as influenced by irrigated and rainfed cotton crops and their correlation with important soil chemical properties. The results from surface soils revealed that SOC and SIC were ranged from 2.70-9.41 g kg^{-1} and 0.95-14.40 g kg^{-1}, respectively in irrigated soils, while the corresponding values were 2.85-7.90 g kg^{-1} and 1.58-19.40 g kg^{-1}, respectively, in rainfed soils. For 9.1 and 29.1 per cent soils, for 'low' SOC, 29 and 62 per cent soils and for 'high to very high' SIC, 20 and 51 per cent soils respectively were responsible in irrigated and rainfed situations, respectively. In surface soils, SOC content was positively and significantly correlated with CEC, N, K_2O, P_2O_5, S, Fe, Mn, Zn and Cu and negatively and significantly with pH and EC while, SIC content was positively and significantly correlated with pH and ESP and negatively and significantly with N and S.

Keywords: Cotton, nutrients, Correlation, Soil carbon, irrigated, rainfed

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Introduction

Cotton is most important fiber crop ('queen of fibres') which plays very important role in economic and social affairs of people, especially in India. This 'white gold' (cotton) is one of the most important cash crops of Gujarat state. Soil carbon (C) is an important part of the terrestrial carbon pool. Soils are potentially viable sinks for atmospheric C and may significantly contribute to mitigation of global climate change. Hence, soil organic carbon storage has been widely considered as a promising measure for mitigating global climate change through C sequestration in soils [1]. The recycling of the plants carbon in the soil system also depends upon macro and micro faunal activity and on leaf litter quality [2]. However, soil carbon pool comprises of two components: Soil organic carbon (SOC) and soil inorganic carbon (SIC). The SOC pool includes highly active humus to relatively inert charcoal C, while the SIC pool includes elemental C and carbonate minerals *e.g.* gypsum, calcite, dolomite, *etc.* [3].

Materials and Methods

South Gujarat in compassing eleven talukas is distributed in three districts of South Gujarat namely Bharuch (21.30 to 22.00 N, 72.450 to 73.150 E), Surat (20° 10' 596" N, 072° 52' 638"E) and Narmada (21° 52' 028"N, 073° 30' 035"E). Major soils are clayey in texture. The area comes under subtropical climate with semi-arid conditions. The annual rainfall varies in these talukas from 700 to 950 mm. However, Surat city receives little more rainfall *i.e.* about 1200 mm. Distribution of rainfall is not uniform. Moreover, soils fertility status is also medium to poor and a result, yield of cotton (desi or hybrid or *Bt*) crop is not optimum and varies widely from talukas to talukas.

Surface soil samples were collected as per the identified location in each of 11 talukas. Representative surface soil samples were collected from a depth of 0-22.5 cm in each field following *zig-zag* method of sampling and the centre of the field was designated as geo-referenced point of sampling. Total 110 representative surface soil samples were collected from 11 talukas based on x, y coordinates by GPS where cotton is being grown. Soil samples collected from the study area were dried and crushed with the help of wooden rod and passed through 2 mm sieve and then used for the determination of soil organic and inorganic carbon content by adopting standard laboratory methods. SOC was determined by [4] rapid titration method [5]. Carbon in soil exists in SOC and inorganic carbon forms mainly in carbonate minerals, such as calcium carbonate ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). For the purpose of determining SIC in the present study the amount of $CaCO_3$ present in the soil has been considered as SIC and it was determined by the rapid titration method as described by [6]. Similarly, for the SIC the calculation was made using 12 % C values of $CaCO_3$ percentage. The samples were categorized as per the rating limit given in **Table 1**.

Table 1 The ratings for SOC (Walkley and Black, 1934) and SIC ($CaCO_3$) content (Water Resources Department, Pune, 2009)

Sr. No.	Ratings	SOC range (g/kg)	Sr. No.	Ratings	SIC range (g/kg)
I	Low	<5.0	i	Low	<1.2
Ii	Medium	5.0-7.5	ii	Medium	1.2-6.0
Iii	High	>7.5	iii	High	6.0-12.0
			iv	Very High	12.0-18.0

Results and Discussion

Soil organic carbon (SOC)

The SOC content of surface soil from irrigated and rainfed area are presented in **Table 2**. Irrigated soils of six talukas of Bharuch district revealed that SOC content varied wildly from 3.30-9.41 g kg^{-1} *i.e.* 'low to high' with mean value of 6.53 g kg^{-1} showing 30, 50 and 20 per cent soils under 'high', 'medium' and 'low' status of SOC, respectively. Similarly, for Surat city taluka, the SOC content ranged from 5.41-8.55 g kg^{-1} exhibiting only 2 samples under 'high' status and rest belonged to 'medium' status of SOC. However, mean SOC of surface soils of Surat city was 6.82 g kg^{-1}. Coming to irrigated soils of four talukas of Narmada district, it revealed that SOC content ranged from 2.70-7.42 g kg^{-1} (50 per cent came under 'low' and rest belonged to 'medium' category of SOC with mean value of 5.20 g kg^{-1}. When all the irrigated soils of 11 talukas were considered together, it was found that soil SOC varied from 2.70 to 9.41 g kg^{-1} *i.e.* 20.0, 50.9 and 29.1 per cent soils with 'high', 'medium' and 'low' category of SOC, respectively.

In case of rainfed soils of (Table 2) Bharuch district (six talukas) result revealed that SOC content varied wildly from 3.15-7.90 g kg^{-1} *i.e.* 'very low to high' with mean SOC value of 4.95 g kg^{-1}. With respect to status of SOC 50.0 per cent soils belonged to 'low' status, while 46.7 and 3.3 per cent soils came under 'medium' and 'high' 'category of SOC, respectively. Similarly, for Surat city taluka, 60 per cent soils came under 'low' SOC status and 40 per cent soils belonged to 'medium' status showing a range from 4.20-7.21 g kg^{-1} with mean value of 5.52 g kg^{-1}. Surface soils of Narmada talukas (four) revealed that SOC content ranged from 2.85-5.40 g kg^{-1} with mean value of 4.03 g kg^{-1}, whereby 85 per cent soils exhibited 'low' status of SOC and rest were 'medium'. When all the rainfed soils of 11 talukas were considered together, it was found that soil SOC varied from very 'low to high' status *i.e.* from 2.85-7.90 g kg^{-1} showing about 62 per cent soils under 'low' category followed by medium (about 36 %) and high (about 2 %) category of SOC. 29 and 62 per cent surface soils with 'low' status of SOC and 51 and 36 per cent surface soils with 'medium' status, respectively from irrigated and rainfed areas, indicated their suitability below 'marginally suitable' (S3) and 'marginally suitable'(S3), respectively. Low to medium content of SOC in rainfed as well as irrigated soils could be attributed mainly to the warmer climate inducing rapid mineralization coupled with less quantum of external addition of organic matter. Similar reason was also reported by [7]. As SOC affects physical, chemical and biological properties of the soiland plays a crucial role in sustaining soil quality, agricultural crop production and environmental quality [8], for obtaining sustained yield of cotton, soil and environmental quality, addition of more organic matter /manures would be of immense need, particularly in soils of low to medium carbon status. Conservation practices, crop rotation with legume crops and addition of plant residues might play an alternative role for achieving higher status of SOC. So far as low SOC is concerned in irrigated and rainfed soils in 11 talukas, presence of 'low' soil carbon would reflect low productivity and pose constraints in relation to nutritional availability due to poor carbon status which might be low addition of organic matter/ manures/ bio-compost/ compost/vermicompost/ wastes *etc.* in these soils or might be due to continuous mono-cropping with cotton crop which could reduce SOC in these soils. Similar results along with almost same reasons for low carbon and low productivity was put forwarded [9] from Chhattisgarh region.

The variation in SOC content from place to place both irrigated and rainfed soils might be ascribed to addition of varying quantity of organic matters / manures / biocompost *etc.* by farmers, variations in tillage operation/ cultivation by the farmers and difference in rate of decomposition of organic matter due to differences in temperature and precipitations. Further, in case of cotton crop, pigeon pea or chickpea along with cotton with balanced nutrient and supplemental irrigation could be recommended to maintain threshold limit of SOC in soil [10]. When mean SOC content of all irrigated soils was compared with that of rainfed soils, it was noticed that rainfed surface soils were quite inferior to irrigated counter parts showing poor productivity index as opined by [8]. SOC is a good indicator of soil productivity potential. This was possibly due to higher addition of organic matter/ manures/ compost *etc.* in irrigated soils by the farmers, apart from higher biomass production, including root of crop under irrigation and balanced fertilization resulting inhigher litter fall and subsequent deposition under irrigated condition (because of hybrid cotton variety) which ultimately improved the organic carbon content of soils under arable irrigated systems. Results were supported by [11] and [12].

Table 2 SOC and its rating in surface soils of irrigated and rainfed cotton growing 11 talukas of Bharuch, Surat and Narmada district

	No of Samples	SOC (g kg^{-1})		SOC category		
		Range	Mean	Low (<5.0)	Medium (5.0-7.5)	High (>7.5)
Bharuch District Talukas	**Irrigated**					
Bharuch	**5**	5.50-9.41	6.80	**0** (0)	**4** (80)	**1** (20)
Jhagadia	**5**	3.30-8.10	5.31	**3** (60)	**1** (20)	**1** (20)
Jambusar	**5**	4.70-8.40	6.30	**1** (20)	**3** (60)	**1** (20)
Amod	**5**	5.85-9.00	7.14	**0** (0)	**3** (60)	**2** (40)
Vagra	**5**	5.40-8.94	7.02	**1** (20)	**2** (40)	**2** (40)
Hansot	**5**	4.60-8.50	6.58	**1** (20)	**2** (40)	**2** (40)
Overall	**30**	3.30-9.41	6.53	**6** (20.0)	**15** (50.0)	**9** (30.0)
Surat District						
Surat city	**5**	5.41-8.55	6.82	**0** (0)	**3** (60)	**2** (40)
Narmada District Talukas						
Narmada	**5**	5.50-7.42	6.42	**0** (0)	**5** (100)	**0** (0)
Dadiapada	**5**	2.70-7.10	5.12	**3** (60)	**2** (40)	**0** (0)
Tilakwada	**5**	4.05-6.10	5.07	**3** (60)	**2** (40)	**0** (0)
Sagbara	**5**	3.00-6.70	4.18	**4** (80)	**1** (20)	**0** (0)
Overall	**20**	2.70-7.42	5.20	**10** (50.0)	**10** (50.0)	**0** (0)
Overall -11 talukas	**55**	2.70-9.41	6.19	**16** (29.1)	**28** (50.9)	**11**(20.0)
Bharuch District Talukas	**Rainfed**					
Bharuch	**5**	3.60-7.90	5.71	**1** (20)	**3** (60)	**1** (20)
Jhagadia	**5**	3.30-6.45	4.92	**2** (40)	**3** (60)	**0** (0)
Jambusar	**5**	3.70-6.50	4.59	**4** (80)	**1** (20)	**0** (0)
Amod	**5**	3.15-6.15	5.15	**1** (20)	**4** (80)	**0** (0)
Vagra	**5**	4.05-6.40	4.25	**4** (80)	**1** (20)	**0** (0)
Hansot	**5**	3.17-5.85	4.99	**3** (60)	**2** (40)	**0** (0)
Overall	**30**	3.15-7.90	4.95	**15** (50.0)	**14** (46.7)	**1** (3.3)
Surat District						
Surat city	**5**	4.20-7.21	5.52	**2** (40)	**3** (60)	**0** (0)
Narmada District Talukas						
Narmada	**5**	4.10-5.40	4.78	**3** (60)	**2** (40)	**0** (0)
Dadiapada	**5**	2.85-4.94	4.14	**5** (100)	**0** (0)	**0** (0)
Tilakwada	**5**	3.40-4.95	4.33	**5** (100)	**0** (0)	**0** (0)
Sagbara	**5**	3.00-5.35	2.88	**4** (80)	**1** (20)	**0** (0)
Overall	**20**	2.85-5.40	4.03	**17** (85.0)	**3** (15.0)	**0** (0)
Overall -11 talukas	**55**	2.85-7.90	4.83	**34** (61.8)	**20** (36.4)	**1** (1.8)

Values in bold are numbers of samples and values in parenthesis ( ) are per cent of samples.

Soil inorganic carbon (SIC)

The SIC content of surface soil from irrigated and rainfed area of 11 talukas of are presented in **Table 3**. Irrigated soils of six talukas of Bharuch district revealed that SIC content ranged widely from 0.95-14.40 g kg^{-1} *i.e.* from 'low to high' with mean value of 3.80 g kg^{-1}. So far as categorization is concerned, 20, 70 and 10 per cent soils came respectively under 'high', 'medium' and 'low' category of SIC content. Similarly, for Surat city taluka, SIC content ranged from 5.14-6.91 g kg^{-1} with mean value of 5.94 g kg^{-1} showing 20 and 80 per cent soils under 'high' and 'medium' category of SIC content, respectively. In case of four talukas of Narmada district, SIC content widely varied from 1.68-12.10 g kg^{-1} with mean value of 5.06 g kg^{-1} showing 5, 15 and 80 per cent soils respectively with 'high', 'medium' and 'low' category of SIC content. When all the irrigated soils of 11 talukas were considered together, it was found that soil SIC widely varied from 0.95 to 14.40 g kg^{-1}exhibiting high percentage (74.5) of soils under medium SIC content followed by high (18.2 %), low (5.5 %) and very high (1.8 %) category of SIC content. In fact, more the content of SIC, more the chance of problems of crop root growth due to restrictions, soil salinity causing reduction of organic matters [3].

Table 3 SIC and its rating in surface soils of irrigated and rainfed cotton growing 11 talukas of Bharuch, Surat and Narmada district

	No of Samples	SIC (g kg^{-1})*		SIC category			
		Range	**Mean**	**Low (<1.2)**	**Medium (1.2-6.0)**	**High (6.0-12.0)**	**Very high (12.0-18.0)**
Bharuch District Talukas	**Irrigated**						
Bharuch	**5**	0.95-5.40	2.17	**1** (20)	**4** (80)	**0** (0)	**0** (0)
Jhagadia	**5**	1.22-2.41	1.97	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Jambusar	**5**	1.50-9.40	4.62	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Amod	**5**	2.58-6.40	3.76	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Vagra	**5**	4.56-14.40	8.81	**0** (0)	**1** (20)	**4** (80)	**0** (0)
Hansot	**5**	0.96-2.48	1.45	**2** (40)	**3** (60)	**0** (0)	**0** (0)
Overall	**30**	0.95-14.40	3.80	**3** (10.0)	**21** (70.0)	**6** (20.0)	**0** (0)
Surat District							
Surat city	**5**	5.14-6.91	5.94	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Narmada District Talukas							
Narmada	**5**	1.85-4.25	2.97	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Dadiapada	**5**	4.68-12.10	7.07	**0** (0)	**2** (40)	**2** (40)	**1** (20)
Tilakwada	**5**	1.68-7.20	3.98	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Sagbara	**5**	3.18-9.40	6.23	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Overall	**20**	1.68-12.10	5.06	**0** (0)	**16** (80.0)	**3** (15.0)	**1** (5.0)
Overall -11 Talukas	**55**	0.95-14.40	4.93	**3** (5.5)	**41** (74.5)	**10** (18.2)	**1** (1.8)
Bharuch District Talukas	**Rainfed**						
Bharuch	**5**	1.58-5.50	3.04	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Jhagadia	**5**	2.41-5.05	3.44	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Jambusar	**5**	3.58-6.58	4.94	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Amod	**5**	2.83-6.57	4.30	**0** (0)	**4** (80)	**1** (20)	**0** (0)
Vagra	**5**	10.10-11.64	10.85	**0** (0)	**0** (0)	**5** (100)	**0** (0)
Hansot	**5**	1.98-4.54	2.88	**0** (0)	**5** (100)	**0** (0)	**0** (0)
Overall	**30**	1.58-11.64	4.91	**0** (0)	**23** (76.7)	**7** (23.3)	**0** (0)
Surat District							
Surat city	**5**	9.45-19.40	13.45	**0** (0)	**0** (20)	**4** (80)	**1** (20)
Narmada District Talukas							
Narmada	**5**	4.25-8.82	6.24	**0** (0)	**2** (40)	**3** (60)	**0** (0)
Dadiapada	**5**	6.84-10.32	9.54	**0** (0)	**0** (0)	**5** (100)	**0** (0)
Tilakwada	**5**	2.41-8.18	5.48	**0** (0)	**2** (40)	**3** (60)	**0** (0)
Sagbara	**5**	6.72-18.76	10.72	**0** (0)	**0** (0)	**3** (60)	**2** (40)
Overall	**20**	2.27-10.32	8.00	**0** (0)	**4** (20.0)	**14** (70.0)	**2** (10.0)
Overall -11 talukas	**55**	1.58-19.40	8.79	**0** (0)	**27** (49.1)	**25** (45.5)	**3** (5.5)

Values in bold are numbers of samples and values in parenthesis ( ) are per cent of samples.
Note: * g of $CaCO_3$ kg^{-1} of soil is expressed as SIC. Hence, categorization of SIC is based on category of g of $CaCO_3$ kg^{-1} of soil.

Rainfed soils (Table 3) of six talukas of Bharuch district revealed that SIC content widely ranged from 1.58-11.64 g kg^{-1} with mean value of 4.91 g kg^{-1} exhibiting 23.3 and 76.7 per cent soils respectively with 'high' and 'medium' category of SIC content. However, in Surat city taluka, SIC content ranged from 9.45-19.40 g kg^{-1} with mean value of13.45 g kg^{-1} showing 20 and 80 per cent soils respectively with 'very high' and 'high' category of SIC content. In case of four talukas of Narmada district, SIC content ranged from 2.27-10.32 g kg^{-1} with mean value of 10.72 g kg^{-1} showing 10, 70 and 20 per cent soils respectively with 'very high', 'high', and 'medium' category of SIC content. When all the rainfed soils of 11 talukas were considered together, it was found that soil SIC content widely varied from 1.58 to19.40 g kg^{-1} exhibiting 49 per cent soils with 'medium',45.5 per cent soils with 'high' and only 5.5 per cent with 'very high' SIC category. The results indicated that major soils of these talukas either irrigated or rainfed, contain immoderate quantum of SIC. Overall mean SIC of rainfed soils was higher (8.79 g kg^{-1}) as compared to those of irrigated soils (4.93 g kg^{-1}). This might be due to the effect of dissolution process of $CaCO_3$ under irrigated condition, apart from low and erratic distribution of rainfed semi-arid climatic situation which favoured the formation of more $CaCO_3$. Similar result was observed in cotton growing area of Bharuch [13]. In cotton cropping systems SIC was observed higher which might be due to generation of additional HCO^{3-} as a result of irrigation with poor quality water as reported by [10]. The black cotton soils / *Vertisols* from these districts (irrigated + rainfed soils) were developed over granite with patches of basaltic lava hills. The Deccan trap occurs widely in South Gujarat also. The Tapi valley and the South Gujarat plains are formed as a result of recent alluvium of trap origin which has developed black cotton soils containing higher clay content with accumulation of $CaCO_3$. For black cotton soils of Nagpur district, Maharashtra, [14] found high amount of $CaCO_3$ (50 to 248 g kg^{-1}) due to their development from basaltic parent material [15] and [16].

Simple correlations of SOC and SIC content with important soil properties

Simple correlation of SOC and SIC content with different soil properties of 11 talukas (6 talukas of Bharuch district, 4 talukas of Narmada district and 1 taluka of Surat district) of cotton growing areas of South Gujarat are presented in **Table 4**. The results revealed that, SOC content of soils for 6 taluka of Bharuch district was positively and significantly correlated with N (r= 0.35**), S (r= 0.43**), Fe (r= 0.46**) and Zn (r= 0.35**). Though, SOC content was negatively correlated with soil pH, EC and ESP yet the correlations were not to the level of significance. In case of correlations with SIC content, the results revealed that a positively and significant correlation of SIC was observed with ESP (r=0.46**) of soils of 6 talukas of Bharuch district. However, correlations of SIC with pH, P_2O_5, CEC and Cu were positive but not significant. In case of Narmada district, SOC from soils of 4 talukas was positively and significantly correlated with CEC (r= 0.35*), N (r= 0.37*), Mn (r= 0.35*) and Zn (r= 0.31*). Here, correlations of SIC content with ESP, P_2O_5, K_2O, S, Fe and Cu were positive and non-significant**.** For the soils samples of the same areas SIC content was positively and significantly correlated with pH (r= 0.43**) and EC (r = 0.42**), while with ESP, correlation was positive but not significant. But, negative and significant correlations of SIC content were observed with N (r= -0.36*), Fe (r= -0.45**) and Mn (r= -0.38*). Soils of only Surat city taluka showed that SOC content was positively and significantly correlated with P_2O_5 (r= 0.66*) and S (r= 0.78**), while, positively and non-significantly with CEC, N, K_2O, Fe and Zn. In case of SIC content of soils of the same area, it was positively and significantly correlated with ESP (r= 048*) while, positively and non-significantly correlated with pH, EC, K_2O, Fe and Mn. But a negative and highly significant correlation of SIC content was found with S (r= -0.70**).

Table 4: Simple correlation of SOC and SIC content with different soil properties of 11 talukas of cotton growing areas of South Gujarat

Soil properties	6 talukas (irrigated + rainfed) of Bharuch district (n = 60)		4 talukas (irrigated + rainfed) of Narmada district (n = 40)		1 Surat city taluka (irrigated + rainfed) of Surat district (n = 10)	
	SOC	**SIC**	**SOC**	**SIC**	**SOC**	**SIC**
pH	-0.11	0.19	-0.34*	0.43**	-0.03	0.09
EC	-0.29	-0.12	-0.18	0.42**	-0.08	0.41
CEC	0.22	0.22	0.35*	-0.27	0.01	-0.54
ESP	-0.02	0.46**	0.06	0.02	-0.09	0.48*
N	0.35**	-0.24	0.37*	-0.36*	0.44	-0.29
P_2O_5	0.28	0.01	0.27	-0.20	0.66*	-0.30
K_2O	0.17	-0.01	0.13	-0.24	0.32	0.00
S	0.43**	-0.18	0.20	-0.30	0.78**	-0.70*
Fe	0.46**	-0.11	0.25	-0.45**	0.47	0.20
Mn	0.18	-0.20	0.35*	-0.38*	-0.18	0.30
Zn	0.35**	-0.31*	0.31*	-0.15	0.44	-0.02
Cu	0.29	0.06	0.01	-0.01	-0.02	-0.39

** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively

Simple correlation of SOC and SIC content with different properties of soils from all irrigated and rainfed areas are presented in **Table 5**. The results revealed that SOC content was positively and significantly correlated with CEC(r= 0.35**), N(r= 0.51**), P_2O_5(r= 0.37**), K_2O(r= 0.29*), S(r= 0.38**), Fe(r= 0.41**) and Cu(r= 0.26*) in irrigated situation, while with N(r= 0.27*), P_2O_5(r= 0.32*), S(r= 0.34**), Fe(r= 0.29*) and Zn (r= 0.32*) in rainfed soils. However, SOC was negatively and significantly correlated with EC (r= -0.28*) only in rainfed soils. In case of SIC content, it was positively and significantly correlated with pH (r= 0.26*) and ESP (r= 0.34**) in rainfed situation, but no significant correlation of SOC with other parameters. SIC in rainfed situation was negatively correlated with Cu (r= -0.29*).

Table 5 Simple correlation of SOC and SIC content with different soil properties from all irrigated and rainfed areas of South Gujarat

Soil properties	Irrigated soils of 11 talukas (n = 55)		Rainfed soils of 11 talukas (n = 55)	
	SOC	SIC	SOC	SIC
pH	-0.03	0.18	-0.18	0.26*
EC	-0.16	0.04	-0.28*	0.07
CEC	0.35**	0.12	0.11	0.01
ESP	-0.11	-0.01	0.25	0.34**
N	0.51**	-0.20	0.27*	-0.03
P_2O_5	0.37**	-0.13	0.32*	0.03
K_2O	0.29*	-0.02	-0.04	0.11
S	0.38**	-0.12	0.34**	-0.06
Fe	0.41**	-0.14	0.29*	0.06
Mn	0.11	-0.13	0.16	0.00
Zn	0.21	-0.14	0.32*	0.09
Cu	0.26*	0.12	0.01	-0.29*

** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively

Simple correlations of SOC and SIC content from soils of Bharuch (6 talukas), Narmada (4 talukas) and Surat (1 taluka) districts with different soil properties separately of irrigated and rainfed soils are presented in **Table 6**. In irrigated soils of Bharuch district, it was observed that SOC content was positively and significantly correlated with N (r=0.35*), Fe (r= 0.35*) and Cu (r= 0.37*) while, SIC content was positively and significantly correlated with CEC (r=0.47**) and ESP (r= 0.25*) and negatively and significantly correlated with Zn (r=-0.29*). In case of rainfed soils of the same area, SOC content was positively and significantly correlated with N (r=0.34*) and K_2O (r= 0.35*) while, SIC content was positively and significantly correlated with ESP (r= 0.57**). Coming to Narmada district, SOC content of irrigated soils, was positively and significantly correlated with N (r=0.44*) while, SIC content was positively and significantly correlated with EC (r=0.42*) and negatively and significantly correlated with N (r=-0.42*) and Fe (r=-0.49*). In case of rainfed soils of the same areas of Narmada district, correlations of SOC and SIC content were not found significant with any of soil properties. Now, coming to irrigated soils of Surat city taluka, SOC content was found positively and significantly correlated with N (r=0.87*) while, correlations of SIC content was not found significant with any of soil properties.

However, in rainfed soils, SOC content was found negatively and highly significantly correlated (Table 6) with Cu (r=-0.97**) while, SIC was found not to correlate significantly with any of the soil properties. The result of negative correlation between pH and SOC [17]. Negative correlation is perhaps due to the acidic behaviour of humic substances. Present result of positive correlation of SOC with CEC was corroborated [18]. This correlation suggested that soil organic matter contributed to increase soil CEC. Further, the positive correlation between available N and SOC content [9]. Because of definite relation of SOC with soil N as organic matter releases the mineralizable N in a proportionate amount present in the soil, the positive correlation between available N and SOC indicated the phenomenon. The significant correlation (r =0.671*) between available N and SOC, in cotton growing soils whereby he opined that low amount of N present was due to the low organic matter content in soil which might have favoured rapid oxidation and lesser accumulation of organic matter releasing more NO_3^- N, which had been lost by leaching. Again, significant positive correlations of SOC with P_2O_5 and S and of SOC with K_2O [19]. The authors also observed negative correlations of SIC with P_2O_5 (r= - 0.257), K_2O (r= - 0.882) and S (r = -0.136) as we obtained in the present study.

Conclusion

The positive good correlations of SOC content with micronutrients suggested the formation of complexes with organic matter and consequently remained in the forms, easily available to the plants. Similarly, SOC was positively and significantly correlated with Fe (r =0.835**), Mn (r =0.788**), Zn (r = 0.707**) and Cu (r =0.742**) in black soils [20]. Soil organic matter act as promoting chelating agent in promoting the availability of micronutrients [21].

This apart, significant positive correlations of SOC with available Fe (0.62**), Mn (0.65**) and Cu (0.69**) in *Vertisols* of Jabalpur [22]. In case of SIC, correlation with pH in the present study was of the same line as obtained (r = 0.421*) for *Vertisols* of Andhra Pradesh [23]. Increased SOC content with decrease in ESP and increased SIC content with increase ESP [24] and [25].

Table 6 Simple correlations of SOC and SIC content of irrigated and rainfed soils from Bharuch, Narmada and Surat district with different soil properties

Soil properties	6 talukas of Bharuch district - irrigated (n = 30)		6 talukas of Bharuch district - rainfed (n = 30)	
	SOC	**SIC**	**SOC**	**SIC**
pH	0.13	0.03	-0.05	0.29
EC	-0.07	-0.21	-0.34	-0.15
CEC	0.11	0.47**	0.47	0.15
ESP	-0.13	0.25*	0.32	0.57**
N	0.35*	-0.16	0.34*	-0.24
P_2O_5	0.14	-0.01	0.13	0.18
K_2O	0.14	0.10	0.35*	-0.02
S	0.02	-0.05	0.27	-0.13
Fe	0.35*	0.05	0.18	-0.13
Mn	0.17	-0.09	0.04	-0.17
Zn	0.06	-0.29*	0.24	-0.22
Cu	0.37*	0.19	0.09	0.01
	4 talukas of Narmada district - irrigated (n = 20)		**4 talukas of Narmada district - rainfed (n = 20)**	
pH	-0.24	0.34	-0.14	0.18
EC	-0.23	0.44*	0.12	0.26
CEC	0.28	-0.23	0.24	-0.06
ESP	0.19	0.42*	0.25	0.04
N	0.44*	-0.42*	0.09	-0.07
P_2O_5	0.16	-0.23	0.30	-0.01
K_2O	0.08	-0.16	0.31	0.12
S	0.09	-0.21	0.16	-0.17
Fe	0.11	-0.49*	0.31	-0.28
Mn	0.29	-0.07	0.21	-0.31
Zn	0.13	0.21	0.37	-0.16
Cu	0.04	0.38	-0.26	-0.16
	1 Surat city taluka of Surat district-irrigated (n = 05)		**1 Surat city taluka of Surat district - rainfed (n = 05)**	
pH	-0.39	0.19	0.03	0.54
EC	0.39	0.30	-0.45	0.65
CEC	0.11	0.50	0.79	-0.22
ESP	-0.51	0.06	0.94	0.16
N	0.51	-0.23	0.76	-0.25
P_2O_5	0.66	-0.36	0.69	-0.18
K_2O	0.44	-0.74	0.01	0.72
S	0.87*	-0.36	0.44	-0.27
Fe	0.75	0.28	0.06	0.76
Mn	-0.46	0.61	0.20	0.57
Zn	0.54	-0.23	0.22	0.52
Cu	-0.19	-0.63	-0.97**	-0.37

** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively

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