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Physico-chemical Characteristics of Soils of Phansidewa Village of Darjeeling in Perspective of Seasonal Variation, Statistical Distribution and Correlation Matrix

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ABSTRACT

Analysis of soils based on different parameters like soil pH, electrical conductivity (EC), organic carbon (OC), bulk density (BD), clay amount, water holding capacity (WHC), cation exchange capacity (CEC), available nitrogen (N), phosphorus (P), potassium (K), sulphur (S), sodium (Na), calcium (Ca) and magnesium (Mg) was conducted at village Phansidewa of Darjeeling District of West Bengal to determine the physico-chemical parameters by standard methods. The samples were collected from three different sampling stations at three different seasons; pre-monsoon, monsoon, and post-monsoon to be acquainted with seasonal distribution of the soil parameters. All the soil samples were collected at a depth of 0–30 cm and analyzed for the physico-chemical investigation. The values of soil parameters were seeming to be different in the three seasons and also different for three different places. The summary of descriptive statistics and Pearson's correlation coefficient matrix for the studied soil parameters were also analyzed. The information gathered from the analysis would be helpful to the local agrarians to know about the amount of fertilizers to be added in the soil to make it more productive seasonwise.

Key words: *Correlation, Physico-chemical characteristics, Quality, Season, Statistical distribution*

Introduction

The soil can be well-defined as the topmost weathered layer of the earth's crust comprise of mixed organisms and yields of their death and deterioration (Dalwadi and Bhatt, 2008). Soil functions as an imperative role among all of the earthly systems, providing dwelling place for plants, animals, and micro-organisms (Deyn and Van der Putten, 2005).

It is a composite association made up of six different types of constituents, that is organic matter, inorganic matter, soil moisture, soil organisms, soil air soil solution. Approximately, the soil holds 50-60% mineral substance, 25-35% water, 15- 25% air and a little proportion of organic substance (Chatwal and Sharma, 2005). Determination of physico-chemical parameters of soil samples is as important as that of water samples (Verma, 2016, 2017, 2018 and 2019; Singh and Verma, 2016).

Soil quality indicators which help to directly judge the quality of soil and thereby get a clear idea about the various physical, chemical and biological constituents. By assessing soil quality, it is possible to measure various soil parameters, especially some major soil properties such as pH, BD, CEC, clay etc. and their presence in the soil and their potential impact. Along with this, the presence of organic carbon, nitrogen, phosphorus, potassium, sulfur, cal-

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cium, magnesium, etc. in the soil and the amount of nutrients in the soil are very important and all these are particularly important to judge the health of the soil. These physicochemical parameters of soils play a vital role in determining the availability of nutrients in that soils. The amount of nutrients available in the soil depends on the amount of organic matter, calcium carbonate present in the soil, the degree of microbial activity, changes in pH, the amount and nature of the clay present and the condition of soil moisture content (Deshmukh, 2012; Gupta and Gupta, 1997).

Along with place changes, seasonal changes also have an important effect on vegetation, which in turn plays an important role in the abundance of the microbial community present in the soil in consort with nutrient availability (Kumar *et al*., 2021). The importance of changes in the natural environment is evident in agriculture and it has an important role in determining soil health, similarly, seasonal changes have a great impact on the physicochemical parameters of soils. As with the change of season, there is a great change in the ambient temperature, which again has an effect on the activity of the microbial organisms present in the soil, so the importance of seasonal change in determining the quality of the soil is obvious. Along with the natural environment, seasonal changes and other factors cause variations in the nutrients in different layers of the soil and the amount of those nutrients can sometimes be more or less. Differential distribution of accessible nutrients in different depth was described from numerous studies conducted world-wide (Pradhan *et al*., 2016; Amgain *et al*., 2020; Negasa, 2020).

Singh *et al*. (2012) investigated plant community characteristics and soil status in forested state. Kumar et al. highlighted the role of forest in soil of different land use system of North-east, India (Kumar *et al*., 2013). Rawat *et al*. (2019) examined the role of topography on soil excellence of Jharkhand, India.Deteriorating soil superiorityoccurs as an environmental and economic problem rising worldwide as degraded soils become more common due to their rigorous use and poor management, often the consequence of overpopulation (Li and Lindstorm, 2001; Eswaran *et al*., 1997). Also several environmental issues like erosion, compaction, acidification, losses of organic matter as well as nutrients and desertification reduce agricultural production to a great extent (Stocking, 2003). The overall deterioration in soil quality has a severe impact on the atmosphere and agronomic sustainability, population health, food security, and subsistence (Karlen *et al*., 2004). Information about the fertility status of a soil is important for boosting up yields through modern cultivation practices as it is one of the most essential environmental reasons considered as the main source in providing crucial plant nutrients, water reserves, and an intermediate for plant growth (Ghaemi *et al*., 2014).

Declining soil quality emerges as an environmental and economic problem growing worldwide as degraded soils become more frequent due to their intensive use and poor management, often the result of overpopulation (Li and Lindstrom, 2001; Eswaran *et al*., 2005).

Pressing problems like erosion, compaction, acidification, losses of organic matter and nutrients, and desertification decrease agricultural production (Stocking, 2003). The decline in soil quality has a severe influence on the environment and agricultural sustainability, as well as population health, food security, and subsistence (Karlen *et al*., 2004). Sometimes due to the farmer's unreasonable fertilization results in imbalance of soil nutrient, serious soil compaction, declining of production, serious pollution of soil and water, and low quality of agricultural products (Hongguang, 2008). The main objective of the study was to measure the physicochemical properties like pH, EC, BD, clay%, CEC, WHC, OC, available N, P, K, S, Na, Ca and Mg of soil samples from three different sampling stations in three different seasons. Descriptive statistics and Pearson's correlation coefficient matrix for the studied soil parameters were also analyzed and considered for the spatial dependency as well as distribution pattern. Such assessments can be used for optimum fertilization endorsement since suitable use of nutrients can pay to higher crop quantity and superiority, while being environmentally sustainable (Miransari and Mackenzie, 2010).

Soil Sampling and Methodology

Soil samples were collected from village Phansidewa in Darjeeling district. In the village 3 sampling stations were (farmer's field) selected randomly for sampling. Soil samples were collected from the same sampling stations with the help of khurpi, spade, digging bar and meter scale, in pre monsoon, monsoon and post monsoon at the depth 0-15 cm (plough layer); a total of 9 samples were collected with 3 samples representing one sampling station. Samples were collected from centre of the sampling stations in order to avoid the edge effect and carried in a double distilled glass bottles for the experiments.

Electrical conductivity and reaction of the soil samples were determined in 1:2.5 soil: water ratio (w/v) with the help of a combined electrode for EC and pH, as per the procedure given by Jackson (1973). Bulk density and water holding capacity were determined immediately after soil sampling by using separate cores. Water holding capacity was measured by the gravimetric method (Allen, 1989). Bulk density was estimated by the core method (Blake and Hartge, 1986). The percentage of clay was determined by the hydrometer method (Piper, 1966). Cation exchange capacity (CEC) was estimated following method of Jackson (Jackson, 1973). Water holding capacity (%) was determined by international pipette method (Piper, 1966). Total organic carbon in the soil was determined by the wet oxidation method (Allen, 1989). Available N was determined by the Alkaline Permanganate Method (Subbiah and Asija, 1956). Olsen's extractant 0.5 M $NaHCO_3$ (pH 8.5) was used for the extraction of available phosphorus. Phosphorus in the extract was determined calorimetrically by the ammonium molybdate blue colour method using a spectrophotometer at 760 nm (Olsen *et al*., 1954). Available Na and K was determined in the neutral normal ammonium acetate extract of soil with help of a flame photometer (Jackson, 1973). Available Sulphur was determined with 0.15% $CaCl_2$ solution and the S in the extract was estimated turbid metrically (William and Steinbergs, 1959). Exchangeable calcium and magnesium were estimated in the ammonium acetate extract of soil by titration with EDTA(Jackson, 1973).

Results and Discussion

Soil having pH < 5.6 is generally considered as acidic in nature, pH from 5.6 to 6.0 is moderately acidic and pH < 5.5 is considered to be strongly acidic in nature (ICAR, 2005). Proper pH of soil determines the health quality being a very important parameter for the presence of possible nutrient in the soil and also affects the heavy metal solubility and their accessibility to the plants (Reddy and Patrick, 1977; Zeng *et al*., 2011; Zhao *et al*. 2010). The natural forest has comparatively lower pH level in comparison to the grasslands as the organic matter exist in the form of plant litter, compost, and manure shrinkages the soil pH through the decay courses (Brady and Weil, 2002). In the present study, the pH of the soil sample of sampling station 1 was recorded highest (6.95) in the post monsoon and lowest pH (5.43) for the same place in monsoon. The pH was recorded in the order of post monsoon>pre monsoon>monsoon for sampling station 1 and 2 while for the sampling station 3 the trend is post monsoon>monsoon>pre monsoon. It was informed that for balanced nutrient source, and forest soil should be acidic in nature to some extent (Leskiw, 1998). The acidic nature of the soils of cultivated lands might be due to constant agronomy in addition tousing nitrogenous fertilizers as in cultivated lands, ammonium-based manuresgenerally cause soil acidification (Brady and Weil, 2005). In Nepal due to the usage of high level of urea and ammonium phosphates for cultivation, the cultivated soils are made acidic in character (Diwakar *et al.,* 2008).

EC of soil designates total amount of soluble salts in the soil. The conductivity value measures the ions present in the soil samples. In the course of this process the cations of the clay/colloidal matter are exchanged in equivalent amounts with the cations present in the soil. This method of exchanges of cations of soil and salt solution is considered as cation exchange. Soil with EC<4 is considered to be normal in nature. It may cause damage to the crop harvests, obtainability of nutrients to plant, crop sustainability as well as soil microorganism. Surplus salts obstruct plant growth by affecting the soil-water equilibrium. The EC values of the soil samples from study areas ranges from 0.04 to 0.09 dSm^{-1} indicating all the soil samples were normal in nature. Season wise the trend is seen to be post monsoon >pre monsoon >monsoon. In general, the lesser values of EC could be accredited to sandy loam texture, which permits free leaching of solvable salts, and due to small quantities of soluble salts in the original deposits (Sharma *et al*., 2016).

BD values decreases with increased porosity and reduced soil compaction caused by elevation of organic matter content in the soils. In contrary, increase in BD may also be attributed for lesser organic carbon content in the soils. The present analysis shows that in the monsoon season the lowest 1.02 mgm^{-3} and in the post monsoon season the highest 1.41 mgm^{-3} BD value were found at the sampling station 3 whether the permissible limit is <1.10 mgm^{-3}. Fageria *et al*. (2011) opined that in compacted soil, bulk density, microvoids, thermal conductivity and diffusivity rises. Moges *et al.* (2013) have described similar conclusions; where they have exposed that high BD in lower soil layers was due to the effects of weight of the overlying soil and the reduction in soil organic matter content.

Clays have distinctive characteristics varying with their specific place and source. Clays may bind not only noxious materials but also some nutrients like vitamins and trace elements, bringing about a nutritional disproportion for animals (CAST, 2003). The soil moisture commonly depends on void ratio, particle size, clay minerals, organic matter and ground water condition (Yennawar *et al*., 2013) indicating that clay% of the soil has a great impact on soil characteristics. Wetness also depends largely on the porosity of a soil, and consequently clayey soil, having a high porosity generally have larger water content than do sandy soils (Williams, 2005). Thus soil quality may vary with the clay amount. Clay% for the present study ranges from 18.580; sampling station 3 in monsoon; to 39.130 in the post monsoon; sampling station 1 which is little more than the acceptable limit (<30%). As the percentage of clay in the soil increases, the water holding capacity increases accordingly as clay can bind the water molecules more efficiently. Clay content and form of clay minerals determine the magnitude of the soil specific surface area (Petersen *et al*., 1996).

The CEC values displays that it is comparatively high in the studied soil samples. A reasonable clarification for this observation may be the clayey-silty texture of the experimental soils and their high organic carbon matters. The CEC depends upon the amount and nature of colloids present in soils, clay% and its type, pH etc. Koy (2009) presented that for a given soil, the CEC is determined by the comparative quantities of the different colloids (clay, organic, etc.) present in the soil. In the present study the CEC was highest in the post monsoon season 26.54 Cmol Kg^{-1} for the sampling station 2 and lowest in 11.26 Cmol Kg^{-1}, a bit higher than the normal range in the monsoon for the sampling station 3. The higher CEC are associated with the high levels of organic matter present in the soils (Omoko, 1996).

Analogous increase in water holding capacity (WHC) in soils can be associated with diminution in BD of the soil. Also deviation in seasonal accretion of organic matter may be the cause of dissimilarity in porosity and WHC in different seasons. The findings of Jiao *et al.* showed the variation of such physical properties (Jiao *et al*., 2020). The process of puddling in low land paddy cultivation employ shearing and compactive forces that destroys natural structure of soil and result in a condition of reduced pore space (*A guide to citation*, 2008). The value of soil WHC in the present study ranges from 12.35 - 56.47 % and the order was found to be post monsoon > pre monsoon > monsoon except for the sampling station 2. These variations were attributable to the difference in the deepness, clay amount, silt and organic carbon content present in the soils. Bandyopadhyay (2020) also said that the soil WHC is directly related with the soil texture and the greater the soil silt and clay proportions; the higher the soil WHC. Consequently, soils with higher quantity of clay will augment water holding capacity and soil with less water holding capacity gets dried out rapidly and diminishes the growth of plant. Also as the organic matter increases the water holding capacity of soil also increases.

The OC values of the soil samples range in between 10.14 $gmKg^{-1}$ to 24.54 $gmKg^{-1}$ indicating the presence of comparatively higher amount in the soil. Sampling station 2 at monsoon season shows lowest value and station 1 at post monsoon season shows highest value. Concerned to seasonal variations it was found that all three seasons, pre-monsoon, post-monsoon and monsoon shows high organic carbon (OC) value. Higher OC in soils attributed to sufficient moisture accessibility, which led to better plant growth. Comparatively higher OC level is caused by litter and organic residue deposition, irrespective of soil orders or land usage systems and this reduced with depth (Mandal *et al*., 2013) and low organic carbon content might be due to the poor biological activity or the rapid degradation of organic biomass under repeated torrid conditions (Kadry and Arar, 1975).

Plant need nitrogen comparatively to a greater extent than any other macro or micro nutrients but only a small quantity of N is existing for plants use and 98% of total nitrogen remains as organic form which is not taken by plant directly. Plants take up mineral forms of nitrogen including other different forms such as nitrate and ammonia. Through mineralization and decomposing organic matter and fresh plant residues, soil micro-organisms transform the available nitrogen to mineral form of nitrogen. In the present analysis the value of nitrogen level in soils ranges from 84.67 – 134.87 $mgKg^{-1}$ showing an inadequate presence by amount. The season wise trend was seen to be in consequential. The sewage water is also responsible for the significant increase of the nitrogen in the soil as also depicted by Baddesha *et al*., 1997. Abril *et al.* (2007) has reported that accessible nitrogen is apt to loss in the humid area and can hardly show a correlation with grain production.

Phosphorous is a crucial rudiments considered to be a micro-nutrient. Comparatively a bulk quantity of phosphorous is necessary for plant growth. Lowest available P; 13.65 $mgKg^{-1}$ was found in the soil of Sampling station 1 in monsoon season and the highest 32.57 $mgKg^{-1}$ was Sampling station 2 in post monsoon season which are normal in range. And the order of available P is post monsoon > pre monsoon > monsoon for all the soil samples. Presence of higher amount of P could be attributed to the frequent application of organic residues, through leaf litter and fertilizers which on decomposition releases more obtainable P in soils (Chandel *et al*., 2018). This variability effectually displays the impact of land uses and their managing schemes on available P in different soil of an area. Soil P is much greater in the surface layers of all soil profiles studied, and it declines as depth rises. Intensive farming, derisory use of organic manures and P fertilizers, ongoing elimination of crop residues and resulting nutrient deterioration in various soils may all be causative issues to the drop in available P in the soil profiles (Costa *et al*., 2009).

Potassium is a vital nutrient for plant growth. It is also considered as the one of the utmost significant micronutrients. Potassium lacking soil results in reduced plant growth and decreased productivity of yield. soil temperature and the oxygen level present in soil is also influenced by the potassium content of the soil. The movement of potassium in soil varies with the texture of soil. In sandy soil potassium is in factmoveable and can leach out of the root region. The high obtainable K values in might be attributable to nutrient recycling due to dropping leaves of various tree species (Kaur and Bhat, 2017). The highest level of potassium in the present study was seen 158.85 $mgKg^{-1}$ at post monsoon season for sampling site 1 and lowest 111.24 $mgKg^{-1}$ representing normal range in monsoon season for sampling station 2 and

Table 1. Variation in physico-chemical properties of different sampling stations in different seasons

Season	pH	EC dsm^{-1}	BD mg m^{-3}	Clay %	CEC Cmol Kg^{-1}	WHC%	OC $mgKg^{-1}$
Sampling station 1							
Pre monsoon	6.67	0.08	1.1	28.21	21.58	43.12	18.24
Monsoon	5.43	0.04	1.24	29.45	20.14	12.35	12.45
Post monsoon	6.95	0.09	1.38	39.13	23.74	56.47	24.54
Sampling station 2							
Pre monsoon	5.91	0.08	1.21	22.34	25.32	39.57	10.58
Monsoon	5.87	0.07	1.05	21.26	25.12	41.24	10.14
Post monsoon	6.12	0.11	1.28	28.45	26.54	42.15	13.25
Sampling station 3							
Pre monsoon	5.87	0.07	1.13	21.63	13.55	52.26	14.54
Monsoon	6.05	0.07	1.02	18.58	11.26	42.36	14.46
Post monsoon	6.32	0.09	1.41	29.85	19.64	53.17	14.54
	N mg Kg^{-1}	P $mgKg^{-1}$	K $mgKg^{-1}$	S $mgKg^{-1}$	Na $mgKg^{-1}$	Ca $mgKg^{-1}$	Mg $mgKg^{-1}$
Sampling station 1							
Pre monsoon	133.97	18.54	142.25	12.53	35.48	11.26	3.31
Monsoon	130.46	13.65	132.41	10.13	34.79	10.59	2.58
Post monsoon	134.51	19.37	158.85	13.09	43.24	14.65	3.49
Sampling station 2							
Pre monsoon	96.25	24.21	134.87	19.25	29.54	18.24	8.41
Monsoon	84.67	23.87	111.24	14.27	30.28	16.57	7.23
Post monsoon	86.57	32.57	148.75	18.78	33.84	25.48	7.87
Sampling station 3							
Pre monsoon	112.54	29.54	134.41	14.25	45.78	19.24	5.28
Monsoon	123.25	22.69	130.15	10.58	37.82	12.58	5.11
Post monsoon	134.87	30.18	140.24	14.97	49.64	19.35	7.45

the trend for all the soil samples was post monsoon > pre monsoon > monsoon. According to Sumithra, potassium is not an integral part of any major plant constituent but it plays an important role in plant growing, synthesis of protein and maintenance of plant water equilibrium (Sumithra, 2013). The reduction of K is allied with leaching and drainage courses which lead to the obliteration of vegetation (Basumatary and Bordoloi, 1992). Burning of crop stubbles after crop harvest and higher pH value of soil might be the causes for higher amount of accessible K in the agricultural fields. Heavy soils that comprise of more clay% tend to have large reserves of K which are available to the crop and shows higher soil K indices on analysis (Hargreaves, 2015).

The secondary nutrients for the plant growth are considered as calcium, magnesium and sulphur in soils. Sulphur is essential for nitrogen metabolism and protein formation activity. It is equally necessary in improving the soil characteristics and crop productions as well (Chand *et al*., 1977). Three essential amino acids namely cysteine, cystine and methionine that contain S, are essential for protein synthesis and also play important role in the formation of chlorophyll, glucosides and glucosinolates and thiamine in the crops. According to Blair *et al.* (1997) in post-monsoon season, the sulphur content in soil is higher as the rainfall may add a significant quantity of atmospheric sulphur in soil (Blair *et al*. 1997), again the quantity of S deposited may varywith respect to place, being to a greater extent close to the industrial areas. Along with macronutrients sulphur also got an important significance as it plays a great role in the synthesis of proteins, oils, vitamins and flavoured compounds in plants (Sakal *et al*., 1997). It is also called as the fourth most vital plant nutrient (Rathore *et al*., 2015). In the present case the S content varies from 10.13 $mgKg^{-1}$ for sampling station 1 to 19.25 $mgKg^{-1}$ for sampling station 2. Season wise variation of S content was not identical for all the samples though for all the sample the range was within permissible limit.

Soil deliver sodium into the plants. There is also an accretion of sodium from pesticides, herbicides, fertilizers and run off from shallow salt-laden waters and the cessation of minerals which discharge salt. Sodium is not considered as an essential plant nutrient but it has a great impact on the health of the soil. The high quantity of sodium in soil may result in the salinity problem and poor structure. The excess quantity of sodium may reduce the soil permeability, capability to conduct water and air readily, ability to cluster into easily crumbled masses of particle and may also be toxic to the sensitive plants. The present analysis shows that maximum 49.64 $mgKg^{-1}$Na content was post monsoon for sampling station 3 and minimum 29.54 $mgKg^{-1}$ in pre monsoon for the sampling station 2. An intensification of exchangeable Na % would bring about dispersion of the soil macro-colloid and highly dispersed soil is regarded as by defluctuation and crusting (Foth, 1984).

Calcium is a constituent of numerous primary and secondary minerals present in the soil which are the original source of existing forms of calcium. Calcium content for the soil samples under investigation ranges from 10.59 $mgKg^{-1}$ to 25.48$mgKg^{-1}$ that represents a low quantity of Ca in soil. Calcium provides a building block (calcium pectate) for cell walls and membranes and must be present for the formation of new cells. It is a constituent of important plant carbohydrates, such as starch and cellulose. Calcium promotes plant vigor and rigidity and is important to proper root and stem growth (Nathan). Calcium also has a positive effect on soil properties. This nutrient improves soil structure thereby increasing water penetration, and providing a more favorable soil environment for growth of plant roots and soil microorganisms. (https://www.certifiedcropadviser.org/files/certifications/certified/education/self-study/exam-pdfs/159.pdf). The Ca concentration was maximum during post monsoon by pre monsoon and monsoon.

Available magnesium is accessible to plants as the ions Mg^{+2}. Magnesium content in the soil samples ranges from 2.58 $mgKg^{-1}$to 8.41 $mgKg^{-1}$ which is also in lower amount. The seasonal trend is post monsoon > pre monsoon > monsoon except for the sampling station 2. Ca is very important constituent for photosynthesis and plays the role in the activation of many plant enzymes required for growth and synthesis of protein synthesis. Exchangeable calcium and magnesium are considered as secondary nutrients which are essential in moderately smaller yet in significant quantities (Tukura *et al*., 2013). Calcium deficiency is related to pH and very exceptional if the soil pH is satisfactory (Snober *et al*., 2011). Like the present findings, Bini *et al.* have reported that higher magnesium and calcium in grass land habitat than agricultural habitat, maximum in pre-monsoon season, followed by post-monsoon and least in the monsoon (Bini *et al*., 2015).

Table 2. Basic statistics for the soil samples

	pH	EC dsm^{-1}	BD mg m^{-3}	Clay %	CEC Cmol Kg^{-1}	WHC%	OC $gmKg^{-1}$
Sampling Station 1							
Maximum	6.95	0.09	1.38	39.13	23.74	56.47	24.54
Minimum	5.43	0.04	1.10	28.21	20.14	12.35	12.45
Mean	6.35	0.07	1.24	32.26	21.82	37.31	18.41
Median	6.67	0.08	1.24	29.45	21.58	43.12	18.24
SDeviation	0.81	0.03	0.14	5.98	1.81	22.63	6.05
variance	0.65	0.00	0.02	35.75	3.28	511.93	36.56
S Error	0.47	0.015	0.08	3.45	1.05	13.06	3.49
Skewness	-1.50	-1.46	0	1.65	0.59	-1.08	0.13
Range	1.52	0.05	0.28	10.92	3.60	44.12	12.09
Sampling Station 2							
Maximum	6.12	0.11	1.28	28.45	26.54	42.15	13.25
Minimum	5.87	0.07	1.05	21.26		39.57	10.14
Mean	5.97	0.09	1.18	24.02	25.66	40.99	11.32
Median	5.91	0.08	1.21	22.34	25.32	41.24	10.58
S Deviation	0.13	0.02	0.12	3.88	0.77	1.31	1.68
variance	0.02	0.00	0.01	15.03	0.59	1.71	2.83
S Error	0.08	0.01	0.07	2.24	0.44	0.76	0.97
Skewness	1.56	1.29	-1.07	1.58	1.06	-0.84	1.60
Range	0.25	0.04	0.23	7.19	1.42	2.58	3.11
Sampling Station 3							
Maximum	6.32	0.09	1.41	29.85	19.64	53.17	18.45
Minimum	5.87	0.07	1.02	18.58	11.26	42.36	14.46
Mean	6.08	0.08	1.19	23.35	14.82	49.26	15.82
Median	6.05	0.07	1.13	21.63	13.55	52.26	14.54
S Deviation	0.23	0.01	0.20	5.83	4.33	6.00	2.28
variance	0.23	0.01	0.20	5.83	4.33	6.00	2.28
S Error	0.13	0.01	0.12	3.37	2.50	3.46	1.32
Skewness	0.59	1.73	1.17	1.21	1.20	-1.69	1.73
Range	0.45	0.02	0.39	11.27	8.38	10.81	3.99

	N $mgKg^{-1}$	P $mgKg^{-1}$	K $mgKg^{-1}$	S mgKg-^{1}	Na $mgKg^{-1}$	Ca $mgKg^{-1}$	Mg $mgKg^{-1}$
Sampling Station 1							
Maximum	134.51	19.37	158.85	13.09	43.24	14.65	3.49
Minimum	130.46	13.65	132.41	10.13	34.79	10.59	2.58
Mean	132.98	17.19	144.50	11.92	37.84	12.17	3.13
Median	133.97	18.54	142.25	12.53	35.48	11.26	3.31
S Deviation	2.20	3.09	13.36	1.57	4.69	2.18	0.48
variance	4.84	9.55	178.58	2.47	22.02	4.74	0.23
S Error	1.27	1.784	7.72	0.91	2.71	1.26	0.28
Skewness	-1.62	-1.59	0.74	-1.49	1.69	1.55	-1.46
Range	4.05	5.72	26.44	2.96	8.45	4.06	0.91
Sampling Station 2							
Maximum	96.25	32.57	148.75	19.25	33.84	25.48	8.41
Minimum	84.67	23.87	111.24	14.27	29.54	16.57	7.23
Mean	89.16	26.88	131.62	17.43	31.22	20.10	7.84
Median	86.57	24.21	134.87	18.78	30.28	18.24	7.87
S Deviation	6.21	4.93	18.97	2.75	2.30	4.74	0.59
variance	38.57	24.28	359.67	7.56	5.29	22.43	0.35
S Error	3.59	2.85	10.94	1.59	1.33	2.73	0.34
Skewness	1.55	1.72	-0.75	-1.68	1.53	1.49	-0.25
Range	11.58	8.7	37.51	4.98	4.3	8.91	1.18

Table 2. *Continued ...*

	pH	EC dsm^{-1}	BD mg m^{-3}	Clay %	CEC Cmol Kg^{-1}	WHC%	OC $gmKg^{-1}$
Sampling Station 3							
Maximum	134.87	30.18	140.24	14.97	49.64	19.35	7.45
Minimum	112.54	22.69	130.15	10.58	37.82	12.58	5.11
Mean	123.55	27.47	134.93	13.27	44.41	17.06	5.95
Median	123.25	29.54	134.41	14.25	45.78	19.24	5.28
S Deviation	11.17	4.15	5.07	2.35	6.03	3.88	1.31
variance	11.17	4.15	5.07	2.35	6.03	3.88	1.31
S Error	6.45	2.40	2.92	1.36	3.48	2.24	0.75
Skewness	0.12	-1.69	0.46	-1.56	-0.96	-1.73	1.70
Range	22.33	7.49	10.09	4.39	11.82	6.77	2.34

According to Horneck *et al.* (2011) the mean value of soil magnesium content ranged from high during winter to very high during summer quite similar as the present study (Horneck *et al.*, 2011).

On an average, 41 % of Indian soils are lacking of S and it is widespread in coarse textured alluvial, red and lateritic, leached acidic and hill soils and black clayey soils (https://iiss.icar.gov.in/Institute%20Technology/Technology7.pdf). Sulphur uptake and dry matter yield may rise owing to effect of organics present in soil (Kumar *et al.*, 2019). In the present analysis the highest amount of S was found 19.25 $mgKg^{-1}$ in pre monsoon for the sampling station 2 and lowest 10.13 $mgKg^{-1}$ in monsoon for the sampling station 1. The amount was seen to be lower in monsoon for all the sampling stations. Uptake of some necessary nutrients like N, P, K and B may also upsurge by using of sulphur in the soil (Arvind *et al.*, 2018).

Descriptive statistics

Table 2 represents the descriptive statistics with related statistical variables. Minimum and maximum values, means, median, standard error, variance, standard deviation, range, skewness, coefficient of variation of the variables were analyzed to allow better explanations of the occurrence. The values of mean and median were used as primary assessments of central tendency. In case of sampling station 1, the mean values of pH, EC, WHC, N, P, S and Mg are lower than the median, while that for BD mean and median are of same and for clay, CEC, OC, K, Na and Ca the mean values are higher than the median. The standard deviations (SD) of the examined physico-chemical characteristics ranged from 0.027 to 22.626. A low SD indicates that the data points are close to the dataset average, as in the case of EC, BD, Mg etc. and while a high SD shows

Table 3. Correlations matrix between various attributes of soil of Sampling Station 1

	pH	EC	BD	Clay	CEC	MWHC	OC	N	P	K	S	Na	Ca	Mg
pH	1.00*													
EC	1.00	1.00*												
BD	0.17	0.19	1.00*											
Clay	0.56*	0.60*	0.87*	1.00*										
CEC	0.89*	0.90*	0.60*	0.87*	1.00*									
MWHC	0.99*	0.99*	0.30	0.66*	0.94*	1.00*								
OC	0.93*	0.94*	0.52	0.82*	1.00*	0.97*	1.00*							
N	1.00*	1.00*	0.12	0.52	0.87*	0.98*	0.91*	1.00*						
P	1.00*	1.00*	0.13	0.53	0.88*	0.99*	0.92*	1.00*	1.00*					
K	0.88*	0.89*	0.62*	0.89*	1.00*	0.93*	0.99*	0.85*	0.86*	1.00*				
S	1.00*	1.00*	0.18	0.56*	0.90*	0.99*	0.93*	1.00*	1.00*	0.88*	1.00*			
Na	0.70*	0.71*	0.83*	0.98*	0.94*	0.78*	0.91*	0.66*	0.67*	0.95*	0.70*	1.00*		
Ca	0.75*	0.76*	0.78*	0.97*	0.97*	0.83*	0.94*	0.72*	0.73*	0.98*	0.76*	1.00*	1.00*	
Mg	1.00*	1.00*	0.19	0.57*	0.90*	0.99*	0.94*	1.00*	1.00*	0.89*	1.00*	0.71*	0.76*	1.00*

** Significant at the 0.01 level
* Significant at the 0.05 level

that the data points are dispersed across a wide range a sin the case of WHC and K in the present study. Normal distribution of data was assessed based on their skewness, as per Virgilio *et al*., 2007, the data with -1 to +1 skewness were normally distributed (Virgilio *et al*., 2007). And for the present study, skewness of pH, EC, WHC, N, P, S and Mg is <-1 and clay, Na, Ca; >1 indicating the data highly skewed. CEC, K with skewness range from 0.5-1 are moderately skewed. Whether, BD and OC are fairly skewed with the skewness range from -0.5-0.5. The positive and negative values of skewness are the confirmation that the attributes were transported from the source.

Pearson's correlation coefficient matrix

Pearson's correlation coefficient matrix for various physico-chemical characteristics of soil in three seasons at all three study sites was analyzed. This correlation analysis represents an effective methodology to recognize the connections between several different variables and thus becomes very much useful to detect the influencing issues along with the sources of different constituents. Pearson's correlation coefficient analysis is generally used to measure the degree of correlation among the exchangeable cations and physico-chemical parameters of soils. This Correlation relationships of different soil prop-

Table 4. Correlations matrix between various attributes of soil of Sampling Station 2

	pH	EC	ED	Clay	CEC	MWHC	OC	N	P	K	S	Na	Ca	Mg
pH	1.00**													
EC	1.00**	1.00**												
BD	0.83**	0.99**	1.00**											
Clay	1.00**	0.99**	0.82**	1.00**										
CEC	1.00**	0.99**	0.82**	1.00**	1.00**									
MWHC	0.67*	0.59*	0.13	0.67*	0.68**	1.00**								
OC	1.00**	0.99**	0.82**	1.00**	1.00**	0.68**	1.00**							
N	-0.22	-0.13	0.37	-0.23	-0.24	-0.87	-0.24	1.00**						
P	0.99**	0.98**	0.76**	0.99**	1.00**	0.75**	1.00**	-0.33	1.00**					
K	0.87**	0.91**	1.00**	0.86**	0.86**	0.20	0.86*	0.30	0.80**	1.00**				
S	0.75*	0.63*	0.93**	0.55*	0.54*	-0.25	0.54*	0.69**	0.46	0.90**	1.00**			
Na	0.95**	0.92**	0.62*	0.95**	0.96**	0.86**	0.96**	-0.51	0.98**	0.67**	0.27	1.00**		
Ca	1.00**	1.00**	0.84**	1.00**	1.00**	0.65**	1.00**	-0.19	0.99**	0.88**	0.58*	0.94**	1.00**	
Mg	0.20	0.29	0.71**	0.19	0.18	-0.60	0.18	0.91**	0.08	0.66**	0.93**	-0.11	0.22	1.00**

** Significant at the 0.01 level
* Significant at the 0.05 level

Table 5. Correlations matrix between various attributes of soil of Sampling Station 3

	pH	EC	BD	Clay	CEC	MWHC	OC	N	P	K	S	Na	Ca	Mg
pH	1.00**													
EC	0.92**	1.00**												
BD	0.77**	0.96**	1.00**											
Clay	0.78**	0.97**	1.00**	1.00**										
CEC	0.78**	0.96**	1.00**	1.00**	1.00**									
MWHC	0.19	0.56*	0.77**	0.76**	0.76**	1.00**								
OC	0.91**	1.00**	0.97**	0.97**	0.97**	0.58*	1.00**							
N	1.00**	0.88**	0.71**	0.72**	0.72**	0.10	0.87**	1.00**						
P	0.19	0.57*	0.77**	0.76**	0.76**	1.00**	0.58*	0.10	1.00**					
K	0.67**	0.91**	0.99**	0.99**	0.99**	0.86**	0.91**	0.59*	0.86**	1.00**				
S	0.27	0.63*	0.82**	0.81**	0.81**	1.00**	0.64**	0.18	1.00**	0.90**	1.00**			
Na	0.43	0.75**	0.90**	0.90**	0.90**	0.97**	0.76**	0.34	0.97**	0.96**	0.99**	1.00**		
Ca	0.13	0.51	0.73**	0.72**	0.72**	1.00**	0.53	0.04	1.00**	0.83**	0.99**	0.95**	1.00**	
Mg	0.89**	1.00**	0.98**	0.98**	0.98**	0.62*	1.00**	0.84**	0.62*	0.93**	0.68**	0.79**	0.57*	1.00**

** Significant at the 0.01 level
* Significant at the 0.05 level

erties were determined where (**) and (*) were attributed to significant at the 0.01 level and significant at the 0.05 level, correspondingly. Table 3, 4, 5 displays this correlation coefficient matrix for the soil of sampling station 1, 2 and 3 respectively. It has been observed thatall of the soil attributes for the sampling station 1 and 2 as represented in Table 3 and 4, show positive correlation among them indicating positive relation being a good indicator of soil fertility which is very significant for plant growth and development. On the contrary, for the sampling station 2, the correlation among the soil attributes as depicted in Table 4 shows relationship having significant and positive effect of few soil attributes along with negative correlations for N with pH, EC, BD, Clay, CEC, MHWC, and OC. Also for P with N, S and Mg with MWHC, Na and Ca with N, Mg with Na show negative correlation.

Conclusion

This study provides the comprehensive analysis of physical and chemical parameters of soil samples of three different sampling stations in three different seasons. The results indicated comparatively higher concentrations of majority of soil physical and chemical parameters, especially in post monsoon than pre monsoon and monsoon season. This work is useful to the soil resource managers and agriculturalists. Hence, the soil fertility is good and very important for plant growth and development in agriculture process for sustainable development. The study will help the farmers for implementing integrated nutrient management practice to sustain ideal concentration of all the crucial nutrients for plant growth. As because the physical and chemical properties of the soil is different by place, region, weather etc. so, inspection of the soil characteristic will deliver information that can be used to regulate the use of essential nutrients needed for plants and how much fertilizer should be applied for the betterment of agricultural production. Therefore, special emphasis to be given in inspiring farmers to implement best management strategy for enhancing soil fertility status of soils differently in different seasons to increase production as well as livelihood by maintaining the soil health for food security and increasing agrarian production.

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Conflict of Interest- None

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