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# SOIL NUTRIENT STATUS OF MULBERRY (MORUS SPECIES) GROWING FIELDS IN WEST BENGAL, INDIA

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## ABSTRACT

**Background:** West Bengal with 15734 hectares of mulberry plantation is ranked fourth among the 26 states practicing mulberry sericulture in India. The mulberry leaves are utilized as feed for rearing silkworms and produce raw silk. Because of zilch to limited practice of soil test report based fertilizer application among the sericulture farmers of West Bengal, they are prone to get suboptimal crop yield. In order to streamline the fertilizer application among the farmers, Government of India (GoI) in 2015 launched a flagship programme called 'Soil Health Card' (SHC) scheme for monitoring health of Indian soils. **Objective:** Analysis of nutrient status and soil parameters of composite soil samples from five major sericulture districts of West Bengal. **Methods:** The soil samples were analysed following standard procedures prescribed in a quantitative soil test minilab kit. Further classification of soil nutrient status was prepared in accordance with the SHC Portal of GOI and the results were analysed. **Results:** The mulberry growing soils in studied areas were predominantly acidic (pH $\leq$ 6.5; 67.5% samples) and deficient in sulphur [Nutrient Index Value (NIV) = 1.53; 67%], followed by potassium (NIV = 1.56; 53%) and boron (18%). Further Karl Pearsons' correlation analysis explicated that soil pH and OC has negative and positive significant correlation with most of the nutrients in the studied area, respectively. pH has significant negative correlation with N, P, K, Fe, Mn and Cu and positive correlation with S and B in the plains of West Bengal; and OC significantly correlated negatively with B and positively with N, K, Zn, Fe and Mn. Conversely, pH has significant negative correlation with Zn, Fe, Mn and Cu; positive correlation with P and S; and OC has significant positive correlation with N, B and Mn in the hills of West Bengal. **Conclusion:** Based on the results, block wise soil test based dose of fertilizers and chemicals were prescribed to ameliorate problematic soil parameters of the reported locations.

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# INTRODUCTION

Soil nutrient status forms an important foundation for any crop to be successful or failure. In sericulture, soil health of mulberry growing fields plays an essential role in obtaining optimum yield and sustainable growth. Total area under mulberry cultivation in West Bengal is estimated to be 15,734 ha (CSB, 2020). Sericulture is traditionally practiced in Birbhum, Murshidabad, Malda and Nadia districts of West Bengal (Bose and Kar, 2010). Moreover, hills of Kalimpong district also are one of the principal mulberry sericulture zones along with plains in West Bengal (Ram and Maji, 2018). Sericulture farmers generally undertake silkworm rearings 5 times a year in West Bengal (Bose and Kar, 2010). As a result, frequent removal of assimilatory appendages (~5times/year) occurs in mulberry plants. However, systematic assessment of fertility status of mulberry growing soils in West Bengal is meagre (Samanta *et al.,* 2002). If the field is not compensated adequately for the depleted nutrients by adding chemical fertilizer(s), the soil nutrient status would deteriorate and resultant leaf yields might not be optimal (Bennet *et al.*, 1993). However, indiscriminate application of fertilizer(s) could cause deleterious effects on the field soil (Singh *et al.,* 2018; Lin *et al.*, 2019) and affect leaf and cocoon yields and quality (Chen *et al.*, 2009; Pandiaraj *et al.*, 2017). Hence, it is quite essential to analyse the field soil condition (*i.e.*, pH and EC) and its nutrient status (*i.e*., organic carbon; available nitrogen, phosphorous, potassium, sulphur, zinc, boron, iron, manganese and copper) for judicious application of fertilizers based on soil test recommended doses (Kar *et al.*, 2018; Sudhakar *et al*., 2018).

Government of India (GoI) launched a flagship programme called 'Soil Health Card' (SHC) scheme for monitoring health of Indian soils (www.mospi.gov.in) in February 2015. Under this scheme, uniform norms have been followed across different Indian states for soil analysis to diagnose fertility related constraints and also to recommend site-specific fertilizer recommendations. Wherein soil health condition would be assessed with respect to 12 important soil parameters *viz*., (i) macro-nutrients: Nitrogen (N), Phosphorus (P), Potassium (K); (ii) secondary nutrients: Sulphur (S); (iii) micro-nutrients: Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Boron (B); and (iv) physical parameters: pH, Electrical Conductivity (EC) and Organic Carbon (OC). For judicious application of fertilizer(s), it is necessary to analyse field soil condition (*i.e*., pH and EC) and its nutrient status (*i.e*., organic carbon; available nitrogen, phosphorous, potassium, sulphur, zinc, boron, iron, manganese and copper) of mulberry growing fields in the active sericultural districts of West Bengal, India. It would help to apply soil test based recommended doses of fertilizers and achieve improved quality leaf production.

# MATERIALS AND METHODS

***Study area and collection of soil samples:*** The study area covered 15,243 mulberry growing farmers' fields in 179 villages under three blocks in each of Bhirbhum [Nalhati-I (24.3363°N - 87.8134°E), Nalhati-II (24.301111°N - 87.936111°E) and Rampurhat (24.17°N - 87.78°E)], Murshidabad [Domkal (24.1411927°N - 88.5286903°E), Khargram (24.03427°N - 87.985271°E) and Nabagram (24.0706034°N - 88.0389404°E)] and Malda [Kaliachak-I (24.803°N - 88.029°E), Kaliachak-II (24.96361111°N - 88.08944444°E) and Manikchak (25.0624410°N - 87.9091110°E)] districts; two blocks in each of Nadia [Karimpur-I (23.97944444°N - 88.62194444°E) and Karimpur-II (23.91916667°N - 88.65083333°E)] and Kalimpong [Kalimpong-I (27.06°N - 88.47°E) and Kalimpong-II (27.120°N - 88.593°E)] districts. Representative soil samples were collected as per the operational guidelines of National Mission for Sustainable Agriculture, Ministry of Agriculture and Farmers Welfare, GOI (2016). In brief, 2.5 hectare grid scale system was adopted for irrigated mulberry farms, wherein 0-30cm deep representative surface soil samples were collected from four corners and centre of each ≤2.5 hectare land containing 'n' number(s) of mulberry growing farmers. Collected samples were mixed and reduced to 500g by quartering for obtaining composite sample. However, five representative samples were collected and a composite sample was prepared for individual farmers plot in the hilly terrains/sparse mulberry growing areas. Altogether, 1194 composite soil samples along with required field details were transported to soil testing laboratory at CSRTI-Berhampore for further processing.

***Processing and analysis of soil samples:*** The collected soil samples were air-dried, ground, passed through 2-mm sieve and analyzed following the standard procedures prescribed in Mridaparikshak, a quantitative soil test minilab kit (Nagarjuna Agro Chemicals Pvt. Ltd., Wardha, India). The kit results are comparable to methods of organic carbon (OC) by Walkley and Black (1934); available nitrogen (N) by Subbaiah and Asija (1956); available phosphorous (P) by Olsen *et al.* (1954) & Bray and Kurtz (1945); available potassium (K) by neutral ammonium acetate (Jackson, 1973); available iron (Fe), zinc (Zn), Copper (Cu) & Manganese (Mn) by DTPA extraction (Lindsay and Norvell, 1978) and available boron (B) by hot water soluble methods (John *et al.*, 1975). Soil pH and EC were determined following standard procedures (Jackson, 1973). Classification of soil nutrient status was prepared in accordance with the SHC Portal of GoI (Srivastava *et al.*, 2015).

***Data analysis:***Soil fertility status regarding available OC, N, P, K and S was assessed by calculating nutrient index value (NIV) for each nutrient using following formula as described by Motsara *et al*. (1982).

Nutrient index = $[(Nl \times 1) + (Nm \times 2) + (Nh \times 3)] / Nt$

where, $Nt$ = total number of samples analyzed in given area; $Nl$ = number of samples falling in the low category of nutrient status; $Nm$ = number of samples falling in the medium category of nutrient status; and $Nh$ = number of samples falling in high category of nutrient status. On the basis of NI values, soil fertility level with respect to OC, N, P, K & S levels was categorized as low (if $NI < 1.67$), medium ($1.67 \leq NI \leq 2.33$), or high ($NI > 2.33$). Descriptive statistical and Karl Pearsons' correlation analysis were performed (Sahu, 2007). For correlation study between pH/OC and nutrient availability, pooled data of soil samples were used.

# RESULTS AND DISCUSSION

***Soil reaction, electrical conductivity and organic carbon content*:** Pooled data shows significant variations in soil pH (3.07 to 8.63), EC (0.01 to 3.30 dS $m^{-1}$) and OC content (0.02

to 2.28%) in the analyzed samples (Table 1). About 21.5% of soil samples were strongly acidic (pH < 4.5), 28.9% moderately acidic (4.5≤ pH ≤ 5.5), 17.1% slightly acidic (5.5< pH ≤6.5), 15.6% neutral (6.5< pH ≤ 7.5), 16.4% slightly alkaline (7.5< pH ≤ 8.5) and 0.5% alkaline (pH > 8.5) (Fig. 1 & Table 3). The soil samples from Kalimpong (2.5%), Birbhum (3.1%), Murshidabad (17.1%), Nadia (20.8%) and Malda (38.4%) districts were found to be in neutral pH range. Earlier, Kar *et al.* (2008-2009) reported that the soils of Malda (79% samples), Murshidabad (59%) and Birbhum (31%) districts are under suitable range of pH (6.5-7.5) for mulberry growth. Further, the soils of Kalimpong (97.5%), Birbhum (96.9%) and Murshidabad (77.2%) districts were mostly acidic (pH ≤ 6.5). The results are in concurrence with the findings of Kar *et al.* (2011). The findings indicate deteriorating condition of the soil pH in the region. Moreover, it was observed that the soil pH was ≤5.5 in 50.4% of studied samples, which indicates that mulberry crop in these fields may starve due to slow nitrification of $NH_4^+$ to $NO_3^-$ (a N-form assimilated by mulberry plant) due to poor microbial activity at such a low pH (Panda, 1987) and can also suffer from aluminium toxicity (Evans and Kamprath, 1970). Earlier, Kar *et al.* (2011) ascribed both exchangeable $Al^{3+}$ and organic matter factors responsible for generating pH-dependent acidity and in turn, total acidity of soils in Eastern India. As organic matter had been reported to have significant correlation with acidity of soil, prevalence of high OC content in the studied region can be associated with the acidity of the soils. Moreover, use of ammonium-based fertilizers clubbed with nitrate leaching due to high rainfall and flood irrigation might also be responsible for the soil acidification (Fageria *et al.*, 2010; Lungu and Dynoodt, 2008). Further, perusal of the findings indicates that soils of Murshidabad (Domkal block: 100%), Malda (56.4%) and Nadia (49.5%) districts were mostly alkaline (pH ≥7.5). Flood irrigation could be one of the reasons for increase in sodicity and pH of the soils (Christine *et al.*, 2018; Shin-ichi, 1991). Prevalence of acidic (67.5% in pooled samples) and alkaline (>49% in some districts) reaction of soils in the studied area can be detrimental in terms of availability of nutrients for mulberry plantations and might lead to disparity in leaf productivity.

In agreement with previous reports (Ram and Maji, 2018; Kar *et al.*, 2008-2009), EC values of the studied region were found to be normal (EC ≤ 2), except for few samples (n = 5/10) from Senpara village of Karimpur-I block of Nadia district, where 16.7% samples were slightly saline (2.04 to 3.4 dS $m^{-1}$). The normal EC in the soils might be attributed to leaching of salts below root zone due to high rainfall (Prasenjit *et al.*, 2018; Kar *et al.* 2011). The quality of ground water used to flood irrigate the fields could also be one of the factors behind occurrence of slightly saline soils (Christine *et al.* 2018). Earlier, CGWB (2016) has reported the presence of high EC (up to 5.17 dS $m^{-1}$) in ground water of inland districts of West Bengal. Organic carbon content was recorded as high in 54%, medium (0.5 < OC ≤ 0.75%) in 24.3% and low in 21.7% of the samples. Higher OC content observed in the samples might be ascribed to the possible accumulation of organic matter in the surface soil. Nevertheless, low to medium OC status in some soil samples (46%) could be attributed to lack of application of recommended dose of farmyard manure. This indicates the need of rejuvenating soil health in these districts as the soil OC content is crucial for deep-rooted mulberry plants.

***Available macronutrient status*:** The mean values of N, P and K in samples were 326, 106 and 161 kg $ha^{-1}$, respectively (Table 1). According to the ratings suggested by Srivastava *et al.* (2015) and Muhr *et al.* (1965), the soil samples based on available N could be categorised into high (1.76% soil samples; >560 kg N $ha^{-1}$), medium (64%; 280 to 560 kg N $ha^{-1}$) and low (34.3%; <280 kg N $ha^{-1}$). The soil samples with low available N status were maximum (65.6%) in Karimpur-II block of Nadia district followed by Malda district (49.6 – 60.9%) in comparison to the other regions. Such low N status of mulberry growing soils might have large scale implications on the N and moisture content of leaf (Prasenjit *et al.*, 2021). The positive effect of N fertilization on mulberry leaf yield and quality in relation to silkworm cocoon characters had been reported by Shankar and Rangaswamy (1999). On the basis of the limit in relation to available P in soil as suggested by Srivastava *et al.* (2015), 12.7% of the soil samples were in low (<23 kg P $ha^{-1}$), 21.3% in medium (23-57 kg P $ha^{-1}$) and 66% in high (>57 kg P $ha^{-1}$) categories. Low P status was found to be prevalent in Malda district (33%) followed by Nadia (30%) and other districts. Precipitation of P as iron and aluminium complexes due to acidic reaction of soil might be one of the reasons for low P status in these soils (Prasenjit *et al.*, 2018). The status of available K in the soil was rated as low (53.4% samples; <145 kg K $ha^{-1}$), medium (36.9%; 145 to 337 kg K $ha^{-1}$) and high (9.72%; >337 kg K $ha^{-1}$) category based on the suggested ratings. Low available K status in the soils may be ascribed to negative K balance scenario developed due to removal of large portion of K (~1.5 times of applied fertilizer) in intensive cropping system (Gurav *et al.*, 2018). Both P and K aid in the efficient utilization of N, which ultimately influences the quality of mulberry leaves (FAO, 1988).

Perusal of data indicates that sulphur content in soils varied from 1.0 to 128 mg $kg^{-1}$ with the mean value being 10.2 mg $kg^{-1}$. The S content was low (< 10 mg S $kg^{-1}$) in 67.2% samples, medium (10 to 15 mg S $kg^{-1}$) in 12.9% samples and high (> 15 mg S $kg^{-1}$) in 19.9% samples. Predominance of low S levels in the region may be attributed to the continuous use of high analysis fertilizer coupled with enhanced rate of sulphur removal by mulberry due to intensive cropping with high yielding varieties and therefore, these fields' needs to be replenished with sulphur fertilizers (Bose and Kar, 2010). Nevertheless, mulberry fields with high level of S (≥35 kg S $ha^{-1}$) do not require application of sulphur fertilizer (Bose *et al.*, 2010a). In order to harness the benefits of high amounts of available S, proper N management is essential for maintaining appropriate N:S ratio in mulberry growing soils as well as mulberry leaves, since both the elements are constituents of protein and S metabolism in plants is closely linked with N (Prasenjit *et al.*, 2018). In view of the requirement to produce quality of mulberry leaves, proper K and S fertilization should be adopted as 53.4 and 67.2% of soil samples were found deficient (low) in available K & S, respectively. Similarly, as > 60% soil samples from Karimpur-II and Kaliachak-II blocks were low in available N, these soils require appropriate N fertilization.

***Available micronutrient status*:** Level of micronutrients in the mulberry growing soils indicated available Zn, B, Fe, Mn and Cu levels in the samples varied from 0.18 to 24.3, 0.09 to 26.0, 0.89 to 42.3, 0.45 to 87.2 and 0.09 to 38.0 mg $kg^{-1}$, respectively (Table 2). Soils collected from the Domkal and Manikchak blocks recorded highest (9.40 mg $kg^{-1}$) and lowest (3.27 mg $kg^{-1}$) Zn content, respectively.

**Table 1. Physico-chemical properties and available macro-nutrients in mulberry growing soils of West Bengal**

| District | Block | pH | EC (dSm$^{-1}$) | OC (%) | N (kg ha$^{-1}$) | P (kg ha$^{-1}$) | K (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Birbhum (509) | Nalhati-I (409) | 3.11-7.81 (4.61±0.64) | 0.02-1.64 (0.32±0.21) | 0.02-2.28 (0.85±0.34) | 28.0-686 (329±97.5) | 2.68-319 (112.2±52.7) | 2.58-508 (185±93.0) |
| | Nalhati-II (75) | 3.24-7.18 (5.34±0.86) | 0.08-1.85 (0.54±0.35) | 0.02-1.72 (0.90±0.43 | 124-547 (342±107) | 18.8-339 (143±87.5) | 15.5-462 (163±115) |
| | Rampurhat-I & II (25) | 3.11-7.21 (5.60±1.08) | 0.06-0.84 (0.33±0.24) | 0.11-1.50 (1.00±0.39) | 147-491 (369±97.2) | 16.1-274 (90.8±70.7) | 31.0-908 (311±281) |
| Kalimpong (81) | Kalimpong-I (32) | 4.35-6.96 (5.28±0.55) | 0.01-0.63 (0.34±0.23) | 0.82-1.92 (1.29±0.28) | 324-601 (441±70.1) | 35.1-290 (122±95.2) | 11.6-569 (330±221) |
| | Kalimpong-II (49) | 4.00-7.36 (5.26±0.63) | 0.03-1.15 (0.26±0.25) | 1.03-1.72 (1.44±0.18) | 374-547 (477±44.7) | 25.9-340 (111±86.3) | 25.8-550 (221±144) |
| Malda (250) | Kaliachak-I (131) | 6.06-8.63 (7.50±0.48) | 0.09-1.29 (0.42±0.27) | 0.04-1.59 (0.70±0.34) | 130-656 (301±94.9) | 1.78-947 (89.3±164) | 4.32-394 (88.6±89.9) |
| | Kaliachak-II (110) | 5.63-8.52 (7.56±0.52) | 0.06-1.27 (0.40±0.26) | 0.13-2.26 (0.65±0.42) | 152-680 (280±104) | 1.79-122 (35.6±21.9) | 6.44-428 (111±112) |
| | Manikchak (9) | 6.69-7.30 (7.03±0.20) | 0.49-0.74 (0.62±0.09) | 0.47-0.91 (0.72±0.16) | 235-347 (298±39.5) | 14.7-165 (57.2±47.7) | 23.2-210 (73.1±55.7) |
| Murshidabad (263) | Domkal (6) | 7.86-8.11 (8.04±0.10) | 0.57-0.64 (0.61±0.03) | 0.47-1.34 (0.85±0.34) | 235-452 (331±84.4) | 17.9-59.0 (35.5±16.0) | 381-395 (390±5.05) |
| | Khargram (120) | 3.07-8.02 (5.48±0.97) | 0.01-1.12 (0.39±0.30) | 0.17-1.97 (0.77±0.36) | 163-608 (307±88.6) | 6.13-322 (168±79.3) | 8.70-506 (190±128) |
| | Nabagram (137) | 4.00-8.46 (5.85±0.92) | 0.05-1.64 (0.33±0.27) | 0.04-1.70 (0.73±0.33) | 130-641 (314±91.9) | 2.68-287 (115±67.2) | 2.58-510 (150±105) |
| Nadia (91) | Karimpur-I (30) | 4.18-8.06 (6.31±1.43) | 0.06-3.30 (1.05±0.90) | 0.15-1.68 (1.08±0.43) | 158-536 (388±107) | 0.89-193 (40.8±38.3) | 1.29-86.4 (44.6±23.1) |
| | Karimpur-II (61) | 5.34-8.29 (7.51±0.54) | 0.07-0.85 (0.18±0.10) | 0.11-1.20 (0.55±0.27) | 141-419 (258±69.5) | 1.79-257 (73.6±66.9) | 5.16-205 (48.4±40.1) |
| Pooled samples (1194) | | 3.07-8.63 (5.76±1.36) | 0.01-3.30 (0.37±0.31) | 0.02-2.28 (0.83±0.39) | 28.0-686 (326±103) | 0.89-947 (106±87.4) | 1.29-908 (161±128) |

++Figures in parenthesis indicate number of soil sampling points; #Figures in parenthesis indicate (mean± standard deviation)

**Table 2. Status of available sulphur and micro nutrients in mulberry growing soils of West Bengal**

| District | Block | S (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | B (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Birbhum (509) | Nalhati-I (409) | 1.00-46.0 (5.47±4.73) | 0.18-24.3 (4.69±3.03) | 0.09-15.2 (1.55±1.88) | 5.37-42.3 (32.2±4.95) | 0.90-87.2 (35.1±18.3) | 0.09-33.5 (6.07±5.30) |
| | Nalhati-II (75) | 1.00-74.0 (16.1±17.2) | 0.18-16.6 (3.77±3.96) | 0.21-20.6 (3.10-3.24) | 5.93-36.5 (27.8±5.79) | 0.68-45.8 (10.5±11.6) | 0.09-36.5 (12.5±10.3) |
| | Rampurhat-I & II (25) | 1.21-17.53 (5.69±4.39) | 0.24-18.3 (7.98±6.48) | 0.27-4.90 (1.78±1.17) | 7.06-31.5 (19.7±7.54) | 1.80-28.7 (10.1±9.37) | 0.46-21.4 (4.38±5.84) |
| Kalimpong (81) | Kalimpong-I (32) | 1.00-34.0 (16.1±9.83) | 2.11-16.7 (9.26±4.95) | 1.28-5.52 (2.85±0.95) | 15.5-33.7 (27.1±5.44) | 1.35-10.2 (4.90±2.61) | 3.18-38.0 (15.3±10.8) |
| | Kalimpong-II (49) | 1.00-45.0 (14.1±8.68) | 1.73-15.3 (5.35±3.31) | 1.74-9.01 (4.04±1.39) | 17.2-34.1 (26.1±4.18) | 1.35-24.7 (6.36±5.40) | 0.74-32.7 (6.71±8.77) |
| Malda (250) | Kaliachak-I (131) | 1.00-52.5 (8.85±9.43) | 0.18-14.4 (4.99±3.61) | 0.09-20.1 (2.31±2.57) | 0.89-32.0 (15.0±7.26) | 0.45-20.2 (5.65±4.63) | 0.09-13.7 (3.09±2.79) |
| | Kaliachak-II (110) | 1.00-83.0 (20.0±18.0) | 0.32-10.3 (3.51±2.31) | 0.09-9.47 (1.49±1.27) | 1.90-29.2 (14.2±6.54) | 0.45-24.7 (7.32±6.08) | 0.09-19.5 (4.41±4.23) |
| | Manikchak (9) | 6.00-41.0 (25.1±11.0) | 2.03-4.99 (3.27±1.06) | 0.27-7.17 (2.99±2.58) | 11.6-26.4 (18.7±4.53) | 5.83-13.0 (10.1±2.43) | 3.08-11.6 (5.53±2.74) |
| Murshidabad (263) | Domkal (6) | 4.23-6.05 (5.24±0.65) | 7.58-11.0 (9.40±1.25) | 0.29-2.63 (1.17±1.02) | 7.72-12.4 (9.62±1.74) | 1.07-1.41 (1.27±0.13) | 0.21-0.47 (0.34±0.09) |
| | Khargram (120) | 1.00-36.0 (10.2±7.50) | 0.18-15.7 (4.82±3.50) | 0.09-20.6 (3.11±3.07) | 10.7-35.0 (29.5±5.01) | 1.80-58.4 (15.8±15.0) | 0.46-35.1 (9.76±7.74) |
| | Nabagram (137) | 1.00-128 (13.0±22.4) | 0.18-12.3 (3.37±2.91) | 0.09-12.4 (3.01±2.35) | 3.69-35.3 (24.2±7.06) | 0.45-61.6 (18.1±15.2) | 0.71-35.5 (6.97±6.89) |
| Nadia (91) | Karimpur-I (30) | 1.21-17.8 (4.80±3.35) | 0.18-13.8 (5.30±4.72) | 0.09-2.66 (0.96±0.82) | 2.01-27.2 (13.5±6.40) | 0.45-11.2 (4.59±3.40) | 1.40-11.3 (4.01±2.33) |
| | Karimpur-II (61) | 1.00-35.4 (9.08±7.88) | 0.18-13.5 (5.10±3.81) | 0.09-26.0 (4.88±7.96) | 4.48-35.0 (16.0±7.74) | 0.45-11.3 (4.09±2.59) | 0.37-23.5 (4.86±3.94) |
| Pooled samples (1194) | | 1.00-128 (10.2±12.8) | 0.18-24.3 (4.68±3.57) | 0.09-26.0 (2.36±2.94) | 0.89-42.3 (25.0±9.32) | 0.45-87.2 (18.6±18.4) | 0.09-38.0 (6.56±6.76) |

Figures in parenthesis indicate number of soil sampling points; #Figures in parenthesis indicate (mean± standard deviation)

The maximum and minimal B content was found in Nadia district, *viz*., Karimpur-I (4.88 mg kg$^{-1}$) and -II (0.96 mg kg$^{-1}$) blocks. Samples from the Nalhati-I block contained highest quantity of both Fe (32.2 mg kg$^{-1}$) and Mn (35.1 mg kg$^{-1}$). Conversely, the Domkal block samples contained lowest quantity of Fe (9.62 mg kg$^{-1}$), Mn (1.27 mg kg$^{-1}$) and Cu (0.34 mg kg$^{-1}$).

Maximum Cu (15.3 mg kg$^{-1}$) levels were found in Kalimpong-I block. According to the critical limit of deficiency in soil suggested for preparation of the soil health card by Srivastava *et al.* (2015) for Zn (0.6 mg kg$^{-1}$), B (0.5 mg kg$^{-1}$), Fe (4.5 mg kg$^{-1}$), Mn (2 mg kg$^{-1}$) and Cu (0.2 mg kg$^{-1}$), only 1.1% of the pooled soil samples were found to be below the critical limit for available Cu, followed by Fe (2.0%), Zn (5.1%), Mn

**Table 3. Distribution of classified physico-chemical properties and macro-nutrients status* of mulberry growing fields in West Bengal**

| District | Block | pH | | | | | | EC | | OC | | | N | | | P | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | StA | MA | SA | N | SB | Al | NS | SS | L | M | H | L | M | H | L | M | H | L | M | H |
| Birbhum | Nalhati-I | 48.7 | 43.0 | 6.85 | 1.22 | Nil | Nil | 100 | Nil | 13.5 | 23.0 | 63.6 | 25.9 | 72.1 | 1.96 | 4.16 | 9.05 | 86.8 | 33.7 | 59.4 | 6.85 |
| | Nalhati-II | 18.7 | 36.0 | 38.7 | 6.67 | Nil | Nil | 100 | Nil | 22.7 | 14.7 | 62.7 | 28.0 | 72.0 | Nil | 4.00 | 17.3 | 78.7 | 54.7 | 37.3 | 8.00 |
| | Rampurhat-I & II | 16.0 | 28.0 | 32.0 | 24.0 | Nil | Nil | 100 | Nil | 12.0 | 16.0 | 72.0 | 20.0 | 80.0 | Nil | 16.0 | 32.0 | 52.0 | 44.0 | 24.0 | 32.0 |
| Kalimpong | Kalimpong-I | 3.13 | 62.5 | 31.3 | 3.13 | Nil | Nil | 100 | Nil | Nil | Nil | 100 | Nil | 96.9 | 3.13 | Nil | 56.3 | 43.8 | 28.1 | 12.5 | 59.4 |
| | Kalimpong-II | 12.2 | 49.0 | 36.7 | 2.04 | Nil | Nil | 100 | Nil | Nil | Nil | 100 | Nil | 100 | Nil | Nil | 30.6 | 69.4 | 34.7 | 44.9 | 20.4 |
| Malda | Kaliachak-I | Nil | Nil | 5.34 | 42.0 | 49.6 | 3.05 | 100 | Nil | 29.0 | 34.4 | 36.6 | 49.6 | 48.9 | 1.53 | 32.1 | 31.3 | 36.6 | 90.1 | 3.82 | 6.11 |
| | Kaliachak-II | Nil | Nil | 5.45 | 29.1 | 63.6 | 1.82 | 100 | Nil | 43.6 | 28.2 | 28.2 | 60.9 | 35.5 | 3.64 | 32.7 | 51.8 | 15.5 | 72.7 | 20.9 | 6.36 |
| | Manikchak | Nil | Nil | Nil | 100 | Nil | Nil | 100 | Nil | 11.1 | 44.4 | 44.4 | 33.3 | 66.7 | Nil | 33.3 | 11.1 | 55.6 | 88.9 | 11.1 | Nil |
| Murshidabad | Domkal | Nil | Nil | Nil | Nil | 100 | Nil | 100 | Nil | 16.7 | 33.3 | 50.0 | 33.3 | 66.7 | Nil | 16.7 | 66.7 | 16.7 | Nil | Nil | 100 |
| | Khargram | 15.0 | 35.8 | 35.0 | 10.8 | 3.33 | Nil | 100 | Nil | 22.5 | 34.2 | 43.3 | 43.3 | 53.3 | 3.33 | 4.17 | 8.33 | 87.5 | 43.3 | 41.7 | 15.0 |
| | Nabagram | 7.30 | 29.9 | 35.8 | 23.4 | 3.65 | Nil | 100 | Nil | 26.3 | 25.6 | 48.2 | 31.4 | 67.2 | 1.46 | 11.7 | 11.7 | 76.6 | 54.7 | 40.9 | 4.38 |
| Nadia | Karimpur-I | 16.7 | 20.0 | 20.0 | 3.33 | 40.0 | Nil | 83.3 | 16.7 | 13.3 | 13.3 | 73.3 | 16.7 | 83.3 | Nil | 26.7 | 50.0 | 23.3 | 100 | Nil | Nil |
| | Karimpur-II | Nil | 1.64 | 1.64 | 42.6 | 54.1 | Nil | 100 | Nil | 47.5 | 31.2 | 21.3 | 65.6 | 34.4 | Nil | 27.9 | 31.2 | 41.0 | 96.7 | 3.28 | Nil |
| Pooled samples | | 21.5 | 28.9 | 17.1 | 15.6 | 16.4 | 0.50 | 99.6 | 0.42 | 21.7 | 24.3 | 54.0 | 34.3 | 64.0 | 1.76 | 12.7 | 21.3 | 66.0 | 53.4 | 36.9 | 9.72 |

Nutrient status is expressed in % of the total samples analyzed; StA: strongly acidic, MA: moderately acidic, SA: slightly acidic, N: neutral, SB: slightly alkaline, Al: alkaline, NS: not saline, SS: slightly saline, L: low, M: medium, H: high

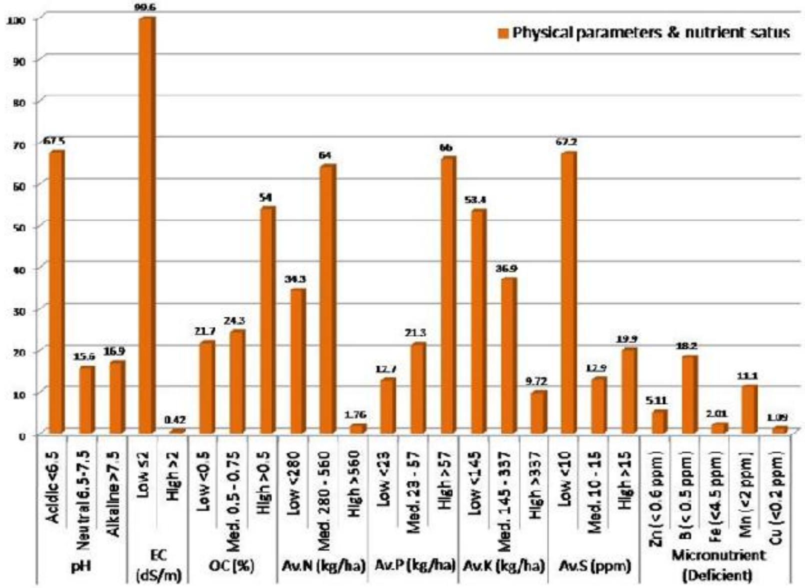


**Fig. 1. Distribution of soil nutrient parameters of mulberry growing fields in West Bengal**

**Table 4. Distribution of classified sulphur and micro-nutrients status* of mulberry growing fields in West Bengal**

| District | Block | S | | | Zn | B | Fe | Mn | Cu |
|---|---|---|---|---|---|---|---|---|---|
| | | L | M | H | Deficient | | | | |
| Birbhum | Nalhati-I | 84.4 | 11.3 | 4.40 | 4.40 | 25.9 | Nil | 0.98 | 0.49 |
| | Nalhati-II | 56.0 | 9.33 | 34.7 | 9.33 | 6.67 | Nil | 9.33 | 6.67 |
| | Rampurhat-I & II | 84.0 | 8.00 | 8.00 | 20.0 | 4.00 | Nil | 16.0 | Nil |
| Kalimpong | Kalimpong-I | 31.3 | 18.8 | 50.0 | Nil | Nil | Nil | 21.9 | Nil |
| | Kalimpong-II | 32.7 | 28.6 | 38.8 | Nil | Nil | Nil | 10.2 | Nil |
| Malda | Kaliachak-I | 66.4 | 13.7 | 19.9 | 1.53 | 13.7 | 9.16 | 29.8 | 3.82 |
| | Kaliachak-II | 33.6 | 10.9 | 55.5 | 1.82 | 23.6 | 8.18 | 29.1 | 0.91 |
| | Manikchak | 11.1 | 11.1 | 77.8 | Nil | 11.1 | Nil | Nil | Nil |
| Murshidabad | Domkal | 100 | Nil | Nil | Nil | 33.3 | Nil | 100 | Nil |
| | Khargram | 59.2 | 23.3 | 17.5 | 3.33 | 13.3 | Nil | 0.83 | Nil |
| | Nabagram | 69.3 | 5.84 | 24.8 | 8.03 | 11.7 | 0.73 | 5.11 | Nil |
| Nadia | Karimpur-I | 96.7 | Nil | 3.33 | 13.3 | 43.3 | 3.33 | 30.0 | Nil |
| | Karimpur-II | 68.9 | 16.4 | 14.8 | 13.1 | 21.3 | 1.64 | 19.7 | Nil |
| Pooled samples | | 67.2 | 12.9 | 19.9 | 5.11 | 18.2 | 2.01 | 11.1 | 1.09 |

**Table 5. Nutrient index values of OC, N, P, K and S in soil samples collected from different mulberry growing blocks of West Bengal.**

| District | Block | Nutrient index/ nutrient status | | | | |
|---|---|---|---|---|---|---|
| | | OC | N | P | K | S |
| Nadia | Karimpur-I | 2.60; H | 1.83; M | 1.97; M | 1.00; L | 1.07; L |
| | Karimpur-II | 1.74; M | 1.34; L | 2.13; M | 1.03; L | 1.46; L |
| Birbhum | Nalhati-I | 2.50; H | 1.76; M | 2.83; H | 1.73; M | 1.20; L |
| | Nalhati-II | 2.40; H | 1.72; M | 2.75; H | 1.53; L | 1.79; M |
| | Rampurhat-I & II | 2.60; H | 1.80; M | 2.36; H | 1.88; M | 1.24; L |
| Kalimpong | Kalimpong-I | 3.00; H | 2.03; M | 2.44; H | 2.31; M | 2.19; M |
| | Kalimpong-II | 3.00; H | 2.00; M | 2.69; H | 1.86; M | 2.06; M |
| Malda | Kaliachak-I | 2.08; M | 1.52; L | 2.05; M | 1.16; L | 1.54; L |
| | Kaliachak-II | 1.85; M | 1.43; L | 1.83; M | 1.34; L | 2.22; M |
| | Manikchak | 2.33; M | 1.67; M | 2.22; M | 1.11; L | 2.67; H |
| Murshidabad | Domkal | 2.33; M | 1.67; M | 2.00; M | 3.00; H | 1.00; L |
| | Khargram | 2.21; M | 1.60; L | 2.83; H | 1.72; M | 1.58; L |
| | Nabagram | 2.22; M | 1.70; M | 2.65; H | 1.50; L | 1.55; L |
| Pooled samples | | 2.32; M | 1.68; M | 2.53; H | 1.56; L | 1.53; L |

**Table 6. Correlation between important soil properties and available nutrients in mulberry growing soils of West Bengal.**

| Important soil properties | Available nutrient in soil (West Bengal plains) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Zn | B | Fe | Mn | Cu |
| pH | -0.19** | -0.31** | -0.33** | 0.16** | 0.03 | 0.07* | -0.72** | -0.57** | -0.26** |
| OC | 0.91** | 0.01 | 0.31** | -0.01 | 0.17** | -0.08* | 0.10** | 0.16** | 0.00 |

**Values of r are significant at 1% probability level; *Values of r are significant at 5% probability level (N= 1113)

| Important soil properties | Available nutrient in soil (Kalimpong hills) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Zn | B | Fe | Mn | Cu |
| pH | -0.05 | 0.46** | -0.20 | 0.47** | -0.24* | -0.11 | -0.37** | -0.42** | -0.29** |
| OC | 1.00** | -0.19 | -0.02 | -0.02 | -0.03 | 0.34** | 0.02 | 0.24* | -0.07 |

**Values of r are significant at 1% probability level; *Values of r are significant at 5% probability level (N= 81)

**Table 7. Recommendation for amelioration of problematic soils in traditional sericultural areas of West Bengal**

| District | Block | Recommendation* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | FYM (t/ha) | N:P:K:S[a] (kg/ha/yr) | Lime[b] (kg/ha) | Zn (% twice/crop) | B | Fe | Mn | Cu |
| Nadia | Karimpur-I | 20 | 336:180:140:50 | 337 | 0.2 | 0.1 | 0.1 | 0.1 | NR |
| | Karimpur-II | 20 | 420:180:140:50 | NR | 0.2 | 0.1 | 0.1 | 0.1 | NR |
| Birbhum | Nalhati-I | 20 | 336:180:112:50 | 1687 | 0.2 | 0.1 | NR | 0.1 | 0.1 |
| | Nalhati-II | 20 | 336:180:140:40 | 1237 | 0.2 | 0.1 | NR | 0.1 | 0.1 |
| | Rampurhat-I & II | 20 | 336:180:112:50 | 787 | 0.2 | 0.1 | NR | 0.1 | NR |
| Malda | Kaliachak-I | 20 | 420:180:140:50 | NR | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| | Kaliachak-II | 20 | 420:180:140:40 | NR | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| | Manikchak | 20 | 336:180:140:40 | NR | NR | 0.1 | NR | NR | NR |
| Murshidabad | Domkal | 20 | 336:180:112:50 | NR | NR | 0.1 | NR | 0.1 | NR |
| | Khargram | 20 | 420:180:112:50 | 1237 | 0.2 | 0.1 | NR | 0.1 | NR |
| | Nabagram | 20 | 336:180:140:50 | 787 | 0.2 | 0.1 | 0.1 | 0.1 | NR |
| Kalimpong | Kalimpong-I | 10 | 150:50:50:NR | 1237 | NR | NR | NR | 0.1 | NR |
| | Kalimpong-II | 10 | 150:50:50:NR | 1237 | NR | NR | NR | 0.1 | NR |

*Calculated based on: a) nutrient index value, and b) average pH of soils in the respective blocks. NR = Not required.

(11.1%) and B (18.2%) (Table 4). Earlier studies have attributed lower content of Zn, Fe and Mn in soils to the higher pH and lower OC content (Prasenjit *et al.* 2018). However, only B and Mn deficient soils were found to be prevalent in the districts in this study with relatively higher pH and lower OC%, *viz*., Nadia, Malda and Mursidabad (Domkal block). Only 2.0% and 5.1% of Fe and Zn deficient soils found in this study, while Samanta *et al*. (2002) reported Fe and Zn deficiency in 25% and 35% analyzed soil samples from mulberry growing fields in West Bengal.

Results indicate that the severity of deficiency of B and Mn is much higher among the micronutrients (Table 4). Boron deficiency was recorded in 4 to 43.3% of the soil samples analyzed across different blocks, except Kalimpong. Similarly, Mn deficiency was recorded in 0.8 to 100% of the samples collected across different blocks excluding Manikchak. Zinc deficiency was observed in many blocks (1.5 to 20 %) apart from Kalimpong, Manikchak and Domkal. Iron deficiency was observed only in Nadia district (1.6 to 3.3%), Kaliachak-I & II blocks of Malda (8.2 to 9.2%) and Nabagram block of Murshidabad districts. Similarly, Cu deficiency was observed only in Nalhati-I & II blocks of Birbhum (0.5 to 6.7%) and Kaliachak-I & II blocks of Malda (0.91 to 3.8%) districts in the study area. The prevalence of B, Mn and Zn deficiencies in the soils might be attributed to the occurrence of inundation as these blocks are proximal to the river Ganges (Bose and Kar, 2010). Prasenjit *et al.* (2018) also has observed the prevalence of B, Zn and Mn deficiency in mulberry growing fields near river Brahmaputra.

***Nutrient index value*:** Nutrient index values (NIV) were calculated to assess the overall nutritional status of OC, N, P, K and S under mulberry cultivation in the study area (Table 5). NIV for available P varied from 1.83 to 2.83 with an overall average of 2.53 indicating high P availability in these soils; for available OC and N in the soil samples varied from 1.74 to 3.00 and 1.34 to 2.03 with an overall average of 2.32 and 1.68 indicating a medium OC and N fertility status in the study area, respectively. All the studied blocks had medium to high NIV for OC status. Data on NIVs for N across different blocks indicated low to medium fertility status of N in the studied area. This might be due to acidification of soils, inadequate or non-application of nitrogenous fertilizers, and limited retention & recycling of mulberry leaf in mulberry gardens unlike the other agricultural crops (Prasenjit *et al.,* 2021). NIV for available K and S varied from 1.00 to 3.00 and 1.00 to 2.67 with the mean value of 1.56 and 1.53, respectively, indicating low fertility status of K and S in these soils. NIVs for available OC, N, P, K and S in different blocks revealed that most of the study areas have low, S and K followed by N. Further, the mulberry growing soils of Karimpur-II and Kaliachak-I exhibited least fertility status in comparison to the other blocks. Both these blocks were found to have low NIV for N, K and S status. Conversely, blocks in Kalimpong district were found to have medium to high NIVs for all the major nutrients. Variations in soil pH, OC, age of mulberry plantations, and indiscriminate application of fertilizers among farmers etc. might be some of the plausible reasons for wide variations in soil nutrient status across the study area.

***Correlation between important soil properties and nutrient availability*:** Soil pH and OC plays a vital role in governing the availability of nutrients in soil for plants. In this study, correlation analysis between these properties and nutrient elements in West Bengals' plain area soils indicated that soil pH had significant negative correlation with N (r = –0.19), P (r = –0.31), K (r = –0.33), Fe (r = –0.72), Mn (r = –0.57) and Cu (r = –0.26); whereas, pH had positive significant correlation with S (0.16) and B (0.07) (Table 6). There was no significant correlation between pH with Zn. Reduced volatilization loss of N at low pH might be the reasons for negative correlation between pH and available N (Prasenjit *et al.,* 2018). In contrast, Kar *et al.* (2011) reported positive correlation of available N with total acidity of soils in West Bengal.

In Kalimpong hills, soil pH had significant positive correlation with P (0.46) and S (0.47); whereas, negative significant correlation with Zn (-0.24), Fe (-0.37), Mn (-0.42) and Cu (-0.29). Contrary to the present study, Kar *et al.* (2011) reported negative correlation of available P with total acidity of soils. Negative relation between pH and K might be due to the fact that with the increase in pH the K-selective exchanges sites, which are blocked by Al at low pH, also increases and makes K susceptible to fixation (Nemeth and Grimme, 1972). The negative correlation between pH and cationic micronutrients might also be due to decreased solubility of these nutrients with increase in pH (Prasenjit et al., 2018). In the soils of West Bengals' plain area, OC had significant positive correlation with N (0.91), K (0.31), Zn (0.17), Fe (0.10) and Mn (0.16); whereas OC had significant negative correlation with B (-0.08). Further, OC had positive significant correlation with N (1.00), B (0.34) and Mn (0.24) in Kalimpong hills indicating the importance of OC on availability of these nutrients in the soil. Kar *et al.* (2008) reported significant effect of OC on availability of N & K in mulberry growing soils of West Bengal. This was ascribed to higher contribution of organic matter (Talashilkar *et al.* 2006) for providing $NH_4^+$-nitrogen and subsequently lesser fixation due to intervention of hydroxyl-aluminium polymers (Panda, 1987). Thus, the findings of this study imply that available nutrient status of soils in these regions can be improved through soil reaction and organic management. Based on the findings, region-specific soil test based dose of fertilizer and chemical application for ameliorating soil problems is recommended (Table 7).

# CONCLUSION

This study shows that mulberry growing fields' of West Bengal are mostly acidic (67.5%) and deficient of available K (53.4%) and S (67.2%). Likewise, B (4 to 43.3%) and Mn (0.83 to 100%) deficiency also was prevalent in the studied area. In the plains of West Bengal, pH has significant negative correlation with N, P, K, Fe, Mn and Cu; whereas, positive correlation with S and B. Further, OC has significant negative correlation with B; whereas, positive correlation with N, K, Zn, Fe and Mn. Conversely, pH has significant negative correlation with Zn, Fe, Mn and Cu; positive correlation with P and S; and OC has significant positive correlation with N, B and Mn in the hills of West Bengal. Thus, the soil nutrient status generated can be used to plan appropriate management interventions in tackling nutrient deficiency in the reported locations by designing region- specific recommendations.

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**Glossary of abbreviation**

B:Boron
cm:Centimetre
CSB:Central Silk Board
CSR&TI:Central Sericultural Research and Training Institute
Cu:Copper
$dSm^{-1}$:Decisiemens per metre
EC: Electrical conductivity
Fe:Iron
g:Gram
GoI: Government of India
K:Potassium
kg:Kilogram
mg:Milligram
mm:Millimetre
Mn:Manganese
N: Nitrogen
NIV:Nutrient index value
OC:Organic Carbon
P: Phosphorus
Pvt. Ltd.:Private limited
S:Sulphur (S)
SHC: Soil Health Card
viz.:Namely
Zn:Zinc

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