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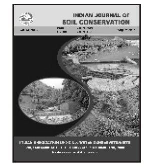

Investigation for determining suitable type of drainage system for salt affected area of Muzaffarpur district of Bihar

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ABSTRACT

The salt affected soils in the state of Bihar are widespread in the northern flood plain of the Ganges covering parts of East and West Champaran, Muzaffarpur, Darbhanga and Saharsa districts. Proper drainage systems are very useful for such areas. In the present study, the salt-affected area located in Muzaffarpur district was selected to study soil parameters in relation to drainage and to investigate whether surface or subsurface drainage is suitable for the area. Three sites with different features were selected from the salt-affected fields. Physical properties such as bulk density, texture, moisture content, porosity, infiltration characteristics and permeability; and chemical properties such as pH, EC, and organic content were determined. After determining pH and EC, the class of salt-affected soil was decided. The results indicated that the bulk density of the soils of all the three sites is high (>1.50 gm cc^{-1}) which results in reduction in pore space. The soils are found to be saline- alkali to alkali in nature. The values of pH are more than 8.5 indicating high ESP which adversely affects the physical properties of soils. The high values of pH throughout the soil depth coupled with high bulk density resulted in reduction in water transmission characteristics of soil *viz.*, permeability and infiltration of the soils. The study infers that a surface drainage system is suitable for the selected salt-affected area.

1. INTRODUCTION

Bihar is having about 1.53 lakh ha of salt affected (saline and alkali) soils (Sharma *et al.*, 2004; http://www.cssri.org) which either produce very low crop yield or no yield. This pulls down the state average yield of crops to a significant level. If the yield of crops on these soils has to be increased, the reclamation of soil is must.

The salt affected soils in the state of Bihar are widespread in the northern flood plain of the Ganges covering parts of East and West Champaran, Muzaffarpur, Darbhanga and Saharsa districts. The districts Gopalganj, Siwan and Chhapra have also appreciable problem of salt affected soils. Area of such land is increasing year by year due to faulty irrigation management, high water table and drainage problems. Proper drainage systems are very useful for such salt-affected areas (Ahmad and Chang, 2002; Yadav *et al.*, 2009; Shakya and Singh, 2010; Noha *et al.,* 2013).

Soil quality for drainage purposes can be classified into physical and chemical properties. Physical properties include texture, density and permeability. The texture class of a soil is determined by the size of soil particles and classes are identified by proportions of sand, silt and clay. The sequence of permeable and impermeable soils and their ability to transmit water plays a significant role in determining the type of drainage system- surface or subsurface, that should be designed and installed. Soil chemical properties as well as physical properties must be considered in evaluating the soil quality for drainage purposes (Verma, 1988; Sahoo *et al.*, 1998; Bendaravicius and Pociene, 2004; Jadhao *et al.,* 2009).

Muzaffarpur is one of salt-affected districts of Bihar mainly drained by river Burhi Gandak, Baghmati and Baya. All three rivers and their tributaries are perennial but these rivers are very unpredictable during rainy season. During monsoon, these rivers become very devastating in nature causing flood in this area. Rajendra Agricultural University, Pusa worked in two blocks, namely Kanti and Motipur of Muzaffarpur district on reclamation of salt affected soils under the NAIP sub-project entitled "Improving livelihood security in salt- affected watersheds of Muzaffarpur and Sheorhar districts of Bihar".

Keeping above views, the present study evaluates physical and chemical properties of soil in relation to drainage in the selected salt affected area to investigate the suitability of surface or subsurface drainage system in the area.

2. MATERIALS AND METHODS

Study Area

The salt-affected area located at Mathina village in Motipur block of Muzaffarpur district was selected for the present investigation. Muzaffarpur district lies in North Bihar *i.e.*, North of Ganga. It covers a geographical area of 3132 Km^2 and falls under 72 F, 72 G and 72 B sheets of Survey of India. It is surrounded by Sitamarhi and East Champaran in North; Vaishali and Saran in South; Darbhanga and Samastipur in East; and Saran and Gopalganj district in West. The selected village has Latitude of $26^0 15'20''$ N and Longitude of $85^0 41'57''$ E. A general survey on the basis of the existing drainage condition was conducted in the selected village to select three sites from the salt-affected fields of Mathina village. The general information on the three sites is presented in Table 1. At each site, soil samples of six different depths *viz.,* 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm were taken for investigation.

Table: 1
Location of the experiment sites

Site No.	Location	Surface Condition	Name of Farmer
1	Near Panchayat Bhawan, Village- Mathina, Block-Motipur Dist.- Muzaffarpur (near Baburban village)	Planted with Sagwan	Sri Shankar Saran
2	West side of main road, Village- Mathina, Block-Motipur Dist.- Muzaffarpur	Paddy-harvested field	Sri Awadhesh Rai
3	East side of main road, Village- Mathina, Block-Motipur Dist.- Muzaffarpur	Paddy-harvested field	Sri Ramuday Yadav

Determination of Physical Properties of Soil

The physical properties of soil determined in relation to drainage were: Soil texture, Bulk density, Moisture content and Porosity.

Soil texture*:* Soil texture was determined by hydrometer method.

Bulk density: Bulk density (BD) of soil was determined using core with known volume. The undisturbed core soil samples were taken from the field, oven dried and weighted. The bulk density was then calculated by the formula:

$$\text{Bulk density} = \frac{\text{Mass of oven dry soil}}{\text{Total volume of core cutter}} \quad ...(1)$$

Moisture content: The moisture content was calculated by standard procedure on oven dry basis.

Porosity: The porosity value in per cent was calculated using following method:

$$\text{Porosity (\%)}=(1\text{-BD/PD})\text{x}100 \quad ... (2)$$

Where, BD= bulk density (gm cm^{-3}) and PD= particle density (gm cm^{-3}).

Determination of Infiltration Characteristics of Soil

Cumulative infiltration and infiltration rate were determined by using double ring infiltrometer at all the three sites *in-situ*. The double ring cylinder infiltrometer has 30 cm inner diameter and 60 cm outer diameter. Cylinders were installed 10 cm deep in the soil. Water level in the inner cylinder was measured with the help of vertically floating scale installed with the instrument. After the initial setting, measurements were made at different time intervals to determine the amount of water that had infiltration during that time. Based on the readings, infiltration rates were computed.

Determination of Permeability of Soil

The permeability of soil was determined with the help of falling head permeability apparatus. In this method, firstly inner length and diameter of the cylinder of the permeability apparatus were measured, and cross-sectional area 'A' was computed. A stand pipe of known cross-sectional area “a” was fitted over the permeameter, and water was allowed to run down. The water level in the stand pipe constantly falls as water flows. At regular time-interval, readings of heads were taken. The co-efficient of permeability (K) *i.e.*, hydraulic conductivity was determined with the help of following formula:

$$K= \frac{aL}{A(t_1 - t_2)} \ln \frac{h_1}{h} \quad ...(3)$$

Where, K = Coefficient of permeability (mm/min), a = cross-sectional area of pipe (mm^2), A= cross-sectional area of soil sample (mm^2), L= Length of soil sample (mm), h_1 and h_2 = water heads (mm) at time t_1 and t_2 (min).

Determination of Chemical Properties of Soil

Soil pH and Electrical conductivity are the two major chemical properties of soil affecting soil health. The pH of soil sample was determined by using pH-meter and EC by EC-meter (Make-Systronics Microprocessor based) in 1:2 soil water suspension. Soil organic carbon was determined by Walkley and Black method (Walkley and Black, 1934). After determining pH and EC, the class of salt-affected soil was decided.

3. RESULTS AND DISCUSSION

Physico-Chemical Properties of Soil

Soils of Site-I: The data of physical and chemical properties of the soil at site-I are presented in Table 2. It is seen from this table that the bulk density value of the soil at this site ranges from 1.57-1.69 gm cm^{-3} with an average value of 1.63 gm/cm^3 indicating poor soil health. The high bulk density of soil is negatively correlated with pore space of soil. The value of pore space ranges from 36.23 to 40.75%. The increase in bulk density resulted in reduction in pore space. The moisture content of soil ranges from 29.11-39.47%. The moisture content was very high at surface indicating poor water transmission from soil surface. The soil texture is found to be sandy loam.

The permeability value of surface soil is found to be 0.13 mm h^{-1} which indicates that the permeability is very low indicating poor water transmission characteristics of the soils. This situation might be due to deterioration of soil structure due to dispersion. The high pH followed by high bulk density and low pore space resulted in reduction in permeability (K = 0.13 mm h^{-1}) and infiltration rate (2.67 mm h^{-1}) of the soil.

The data related to pH and EC (Table 2) indicate that the soil of the present site (site-I) is saline alkali in nature. The value of pH of the top surface soil is less than 8.5 and it contains very high amount of salts as reflected from the value of EC. The surface soil has the highest value of EC (3.16 dS m^{-1}). However, salt content decreases with increasing soil depth. The low organic carbon (< 0.50%) indicates poor fertility status of soil.

Soils of Site-II: The physico-chemical properties of site-II are presented in Table 3. The table indicates that the soil of this site is highly alkaline in nature. The pH ranges from 8.95 to 9.96. However, EC is low and under safe limit for plant growth. The high pH throughout the soil profile adversely affects the physical properties and causes reduction in nutrient balance and availability in soil. The organic carbon content of soil ranges from 0.24 to 0.45 indicating poor soil fertility.

Among the physical properties of soil, bulk density is found to be of high value ranging from 1.58 to 1.70 gm cm^{-3}. The B.D. is high at surface (1.70 gm cm^{-3}) which causes unfavourable environment for plant growth. The higher B.D. value represented reduction in pore space of soil. The pore space varies from 35.85 to 40.38 %. The high bulk density and the low pore space may cause poor water transmission characteristics of the soil. The coefficient of permeability *i.e.* hydraulic conductivity was found to be 0.42 mm h^{-1}. The moisture content of surface soil was high (43.26%) as compared to lower soil depth indicating poor water transmission rate at surface which might be due to low pore space and high bulk density.

Soils of Site-III: The data of physical and chemical properties of site-III are presented in Tables 4. From the table, it is seen that the bulk density value of this site ranges from 1.51-1.66 gm cm^{-3} with an average value of 1.60 gm cm^{-3}. The value of pore space ranges from 37.36 to 43.02%. The high average pH (= 8.83) might have led to dispersion of soil particles resulting into clogging of pore space of the soil and, in turn, a reduction in permeability (K= 0.14 mm h^{-1}) of the surface indicating poor water transmission characteristics of the soils at the surface.

The results on pH, EC and organic carbon (Table 4) indicate that the soil is alkaline throughout the profile. The pH of soil ranges from 8.67 to 8.95. The pH value above 8.5 is detrimental for soil and cause increase in alkalinity and favours accumulation of Na on exchange complex of soil resulting in dispersion of soil leading to deterioration in physical properties. However, data of EC indicated that soil is non-saline and contains very low amount of salts ranging from 0.11 to 0.18 dS m^{-1}. The content of organic carbon ranges from 0.33 to 0.47%. The surface layer (0-15) contains only 0.41% organic carbon indicating low amount of organic carbon which causes poor soil fertility.

Overall Interpretation of the Results on Properties of Soils

Under present findings, the results clearly indicate that

Table: 2
Physical and chemical properties of soil of site-I

S. No.	Sample No.	Soil depth (cm)	B.D. (gm cm^{-3})	Porosity (%)	Moisture content (%) (w.b.)	pH	EC (dS m^{-1})	Organic Carbon (%)
1	1/1	0-15	1.61	39.25	39.47	8.25	3.16	0.36
2	1/2	15-30	1.67	36.98	31.85	8.61	1.04	0.40
3	1/3	30-45	1.69	36.23	32.30	8.74	0.94	0.43
4	1/4	45-60	1.58	40.38	35.63	8.60	0.78	0.42
5	1/5	60-75	1.67	36.98	29.11	8.50	0.52	0.38
6	1/6	75-90	1.57	40.75	32.45	8.70	0.43	0.36
		Average	1.63	38.43	33.47	8.57	1.15	0.39

Table: 3
Physical and chemical properties of soil at site-II

S. No.	Sample No.	Soil depth (cm)	B.D. (gm cm^{-3})	Porosity (%)	Moisture content (%) (w.b.)	pH	EC (dS m^{-1})	Organic Carbon (%)
1	2/1	0-15	1.7	35.85	43.26	9.60	0.19	0.50
2	2/2	15-30	1.61	39.25	20.65	9.18	0.20	0.48
3	2/3	30-45	1.59	40.00	22.04	9.26	0.24	0.56
4	2/4	45-60	1.58	40.38	35.53	9.90	0.32	0.47
5	2/5	60-75	1.68	36.60	30.66	9.96	0.41	0.45
6	2/6	75-90	1.58	40.38	24.11	8.95	0.34	0.43
		Average	1.62	38.74	29.38	9.48	0.28	0.48

Table: 4
Physical and chemical properties of soil at site-III

S. No.	Sample No.	Soil depth (cm)	B.D. (gm cm^{-3})	Porosity (%)	Moisture content (%) (w.b.)	pH	EC (dS m^{-1})	Organic Carbon (%)
1	3/1	0-15	1.66	37.36	31.31	8.88	0.18	0.41
2	3/2	15-30	1.51	43.02	45.52	8.89	0.14	0.40
3	3/3	30-45	1.56	41.13	35.94	8.86	0.13	0.35
4	3/4	45-60	1.58	40.38	27.09	8.95	0.11	0.33
5	3/5	60-75	1.64	38.11	19.04	8.67	0.12	0.47
6	3/6	75-90	1.62	38.87	37.31	8.70	0.14	0.44
		Average	1.60	39.81	32.70	8.83	0.14	0.40

the pH of all the sites is slightly alkaline to moderately alkaline in nature with low to high salinity. The diagnosis of soil revealed that soils of Mathina village (Motipur, Muzaffarpur, Bihar) are saline- alkali to alkali in nature. The exchangeable sodium percentage (ESP) for the surface soil of the sites I, II and III were found to be 26.8, 48.0 and 27.5 respectively. The threshold value of ESP is 15, above which it causes dispersion of soil and which adversely affects the physical properties of soils. The adverse physical properties of soil as reflected from the high bulk density (>1.50 gm cm^{-3}) and high ESP resulted in dispersion of soil particles and clogging of pore space, resulted in reduction of water transmission characteristics of soil *viz.,* permeability and infiltration rate (Table 5). However, for the site-II, the infiltration rate is higher than the other two sites because the organic content is higher for the former site than the latter sites as reflected by the values of organic carbon (Table 2 to 5).

Table: 5
Permeability and infiltration characteristics of soils of different sites

Site	Permeability of surface soil (mm h^{-1})	Infiltration rate at the end of experimental duration (mm h^{-1})
I	0.13	2.67
II	0.42	26.67
III	0.14	1.33

Suitability of Type (Surface or Subsurface) of Drainage System

On the basis of present study, it is found that the soils of Mathina are saline-alkali to alkali in nature. The high values of pH throughout the soil profile coupled with high bulk density resulted in reduction in permeability and infiltration of these soils. The poor soil structure of these soils restricts the movement/transmission of water in soil causing high moisture content in all soil depth. Another reason behind the high moisture contents in all the soil depths is the fact that the water table is very high (< 3 m) causing capillary action throughout the profile in the study area. Therefore, internal (subsurface) drainage system could not be successfully in the soils of this village. Therefore, surface drainage system is suitable for the selected salt-affected area. In other words, there is need to improve surface drainage along with proper reclamation technology and crop management practices to improve soil condition for sustainable crop production. However, as data of the present study is very limited, it needs detailed intensive studies for proper recommendation.

4. CONCLUSIONS

Based on findings of the present study, the conclusions drawn were: (i) Bulk density of soil of all the three sites is high (>1.50 gm cc^{-1}) which causes reduction in pore space; (ii) The soil of all the three sites of Mathina village (Motipur, Muzaffarpur) are saline- alkali to alkali in nature; (iii) The values of pH are more than 8.5 indicating high ESP which adversely affects the physical properties of soil; (iv) The high values of pH throughout the soil profile coupled with high bulk density (>1.50 gm cm^{-3}) resulted in reduction in water transmission characteristics of soil *viz.* permeability and infiltration of the soil; and (v) Surface drainage system along with reclamation measures may be suitable for the current situation.

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