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Laboratory Study on the Black Soil of Percential Influenza on the Need to Subsurface Drainage System

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Abstract

Land is a valuable asset of any country. Its efficient management with a view to conserve its fertility and productivity on sustainable basis is of vital importance for meeting the food demands of the growing population and the development of the country. Agriculture is an important sector of economic activity in India, accounting for a little less than two-fifth of the national income and more than two-third of its work force. However, the agricultural land resources in India are shrinking rapidly as more and more lands are consumed by urbanization, industrial and other developmental activities. If the present trend is an indication, the per capita land availability will be reduced to meager 0.124 ha by the turn of century (Ministry of Environment and Forests, Government of India (GOI), 2012). Therefore, the available land resources have to be properly used as well as the degraded lands be brought back under productive purposes to reduce the pressure on land. The Black soil Clay percentage of soil is the first index to predict this requirement. In this study, in order for the calculation of gradient ratio (GR) and the assessment of clogging potential and soil particles movement into the drainpipe, the permeameter test was carried out on three samples with clay and clay loam textures. Treatments in this experiment were drainage systems with and w/o envelopes. The study area is located between 16^0 23' 56'' N latitude and 80^0 56' 05''E longitude. Vadlamudi is located 22 km away from the district headquarters. In this system with envelope, two types of envelopes (Coconut coir and Nylon mesh) were used. Through the results showed that the values of without envelope in most cases were greater than one which indicates high particle movement potentials. Soil particles movement happened when the values of this index exceeded 3. The ratio of outflow from the systems with mineral and synthetic envelopes to the ones without envelope ranged 2.1-3.7 and 1.5-1.9, respectively. As hydraulic gradient was increased, system hydraulic conductivity decreased in a way that the greater decrease happened in the system without envelope. Furthermore, the results indicated that the system without envelope had the least and the most performance in samples No. 2 and 3, respectively.

Key words : *Black soil percent, permeameter test, envelope, failure gradient, agricultural land.*

Introduction

Increasing demand for food due to thronging population has forced us to develop agriculture in semi-arid to arid lands, which are generally less suitable for agriculture and sensitive to environmental changes. Irrigation has always been considered as an effective way for progressive and sustainable agriculture in rural areas since ancient times. In the post-independent era, huge investments have been made on irrigation development to maximize the agricultural production and achieve quite stable productivity in the country. This was one of the factors that have contributed for the success of the 'Green revolution'. On the other hand, problems of waterlogging and salinity have become serious concern due to unscientific practices of land and water in command areas. Due to these problems, the cultivable lands became degraded and in extreme cases were rendered barren. These problems pose environmental concern and have even raised questions on the investment in irrigation sector.

Excess water in the crop root zone soil is injurious to plant growth. Crop yields are drastically reduced on poorly drained soils, and, in cases of prolonged waterlogging, plants eventually die due to a lack of oxygen in the root zone. Sources of excess soil water that result in high water tables include: high precipitation in humid regions; surplus irrigation water and canal seepage in the irrigated lands and artesian pressure. Once the ground water table rises within 2 m of the soil surface, groundwater contributes substantially to evaporation from the soil surface and water uptake by plants. Since groundwater in arid and semi-arid regions is often rich in soluble salts, the rising water table brings up these salts in the root zone resulting in their gradual accumulation such that, in due course of time, soils become salinized. In the initial years, crop yields are marginally reduced but later cultivation becomes uneconomical and lands have to be abandoned because salts render them completely unproductive.

In order to expedite adoption of land reclamation by subsurface drainage technology, many demonstrations need to be undertaken in farmers' fields in different parts of the command areas in order to convince them.

Materials and Methods

Permeameter Test (Gradient Ratio Determination) : A device in accordance with ASTM D5101-90 was used to

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perform the permeameter test. The main part of the device was a transparent plexiglass cylinder with a diameter of 100 mm and a thickness of 5 mm. This sequence of components in the top cylinder included a drain plate, casing, and soil sample. To analyze the variations of the hydraulic gradient throughout the soil column, some piezometers were set up at certain distances. A drainage plate with four rectangular openings was used in the study (Asghar and Vlotman, 1995). According to the soil bulk density of the study area, soil samples were placed in a cylinder in three layers with a total height of 100 mm. The tests were performed when the systems were saturated. To saturate the systems, the water flow into the system came from below. The height of the inlet tank was then adjusted to create different hydraulic gradients. Gradient ratio tests were performed with five hydraulic slopes (1, 2.5, 5, 7.5 and 10). After creating each gradient, the flow rate from the system, the water height in each pressure gauge and the water temperature were measured at 0, 0.5, 1, 2, 4, 6 and 24 hours after start. . Each test lasted approximately 168 hours (24 hours for each gradient). A total of nine tests were performed (each test had 3 replicates). The tests included three different systems (without shell, with mineral shell and with synthetic shell), each with three soil samples.

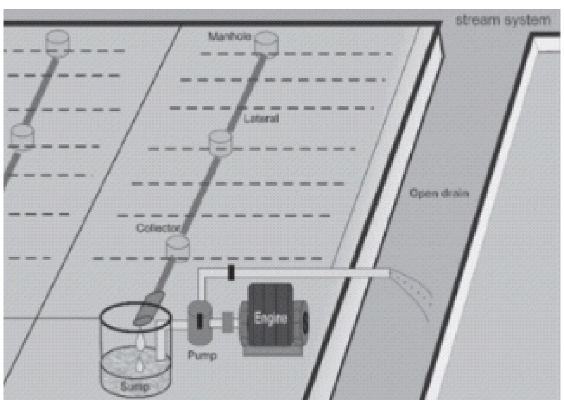

Figure-1 : Schematic layout of Subsurface Drainage system in the Laboratory condition.

Figure-2 : Proto type Layout of subsurface drainage system.

System hydraulic gradient : System hydraulic gradient was calculated from the below equation :

$$i = \frac{h}{l}$$

Where, i = the hydraulic gradient (cm. cm^{-1}),

h = Difference between the water height in (manometers),

l = soil sample length (height, cm).

System Hydraulic Conductivity : System hydraulic conductivity was calculated according to the following equation :

$$K_T = \frac{Q}{iAT \times 100}$$

Where,

K_T = the system permeability at the test temperature (m. sec^{-1}),

Q = the water volume from the system (cm^3),

A = sample section area (cm^2) and

t = time (sec).

Gradient Ratio : In order to analyze the clogging potential of the systems, the gradient ratio (GR) was used according to the following equation :

$$GR = \frac{i_{es}}{i_s}$$

$$i_{es} = \frac{h_{sf}}{L_{sf}} = \frac{(M_3 - M_8) + (M_4 - M_8)}{2L_{sf}}$$

$$i_s = \frac{h_s}{L_s} = \frac{(M_5 - M_3) + (M_6 - M_4)}{2L_s}$$

Where,

GR = the gradient ratio,

i_{es} = the hydraulic gradient of the soil-envelope system,

i_s = the soil hydraulic gradient,

L_{sf} = the length (height) of the soil-envelope system (55 mm) and

L_s = the length (height) of the soil column (45mm).

In case of the gradient ratio of more than 1, the envelope is prone to mineral clogging.

Hydraulic Failure Gradient : Hydraulic failure gradient can be a complementary index to diagnose the need for envelope installation for subsurface drain pipes. This index depends on the fixed physical and mechanical soil properties (saturated hydraulic conductivity, plasticity index). If the exit gradient is less than the hydraulic failure gradient, there is no need for envelope installation.

$$HFG = e^{0.322 \quad 0.312K_s \quad 1.07Ln(PI)}$$

$$i_x \quad \frac{(M_1 \quad M_2) \quad 2M_8}{2l_s}$$

Where,

i_x = the exit gradient,

K_s = the saturated hydraulic conductivity of the soil sample ($m.day^{-1}$),

PI = the plasticity index and

e = the base of natural logarithm.

Results and Discussion

Soil Samples Properties : Physical and chemical properties of three soil samples used in the tests. Sample No. 1 was from *Eshtehard*, Sample No. 2 was from *Khorram Shahr* and Sample No.3 was from *Karaj*. The samples were chosen in a way that the effect of clay percent on the requirement of envelope installation could be analyzed.

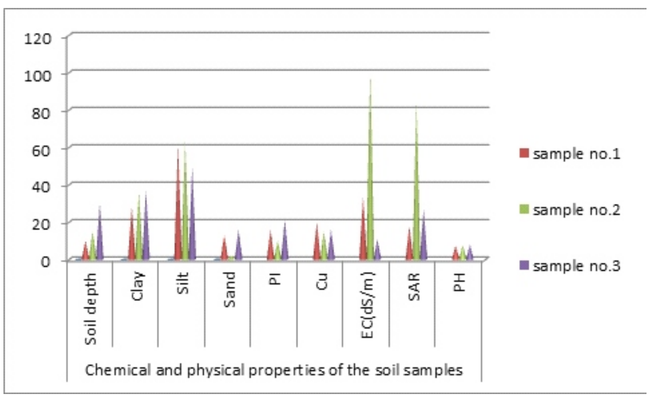

Figure-3 : physical and chemical properties of the soil samples.

The physical and chemical properties of the soil samples were collected 3 samples as sample no. 1, 2, 3 from the field, the clay percent of soil sample were noted as 27, 35, 36, silt percent were noted as 61, 62.2, 49. The sand and PI (plasticity index) noted as 12, 2.8, 15 and 15.4, 9, 20, copper percent and EC (electro conductivity) is 19.7, 14, 16 and 33.2, 100.8, 10.6 & SAR (Sodium Adsorption Ratio) and PH were 17, 83, 26 and 7.42, 7.51, 7.82 respectively

As we can observe that maximum percentage ofphysical and chemical properties of the soil samples for clay in sample no.3, silt in sample no.2, sand in sample no.3, Plasticity index (PI) in sample no. 3, copper in sample no.1, EC in sample no.1, SAR and PH in sample no.2 and sample no.3.

Water Chemical Properties : The water used in the tests was municipal water from Karaj city. Chemical properties of water affect the soil chemical processes. Soil particle dispersion and the hydraulic conductivity are affected by the amount of water solutes and SAR.

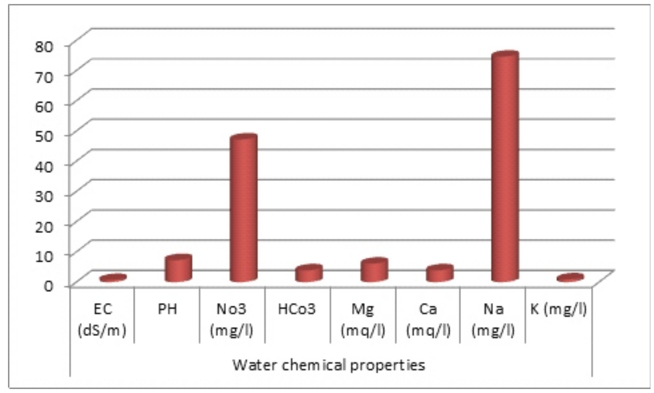

Figure-4 : Chemical Properties of the collected water sample.

The chemical properties of the collected water sample were noted as EC, PH, NO_3, HCO_3, Mg, Ca, Na and K are 0.65, 7.21, 46.72, 3.8, 5.8, 3.8, 73.4 and 0.8 respectively. As we can observe that PH is 7.21 which is base in nature. The nitrate and sodium were recorded as maximum from the collected sample.

Envelopes

Mineral Envelopes : In order to design mineral envelope, the design standards of USBR were used. Using the information obtained from the soil particle size distribution (PSD) curve, according to the samples D_{60} value, the particle distribution of the envelope was chosen.

Synthetic Envelope : As the synthetic envelopes (geotextiles) are getting more and more popular worldwide, in this study, a synthetic envelope model PP-450 (made of propylene) was also assessed.

These fibers are from the waste materials of carpet factories. According to international standards, this kind of envelopes can fulfill the criteria of soil particles stability and mineral clogging prevention. The main reason for choosing this type of synthetic envelopes was the fact that this model had a long study history showed that the performance of this type was better than the others.

Outflow Rate : After measuring the outflow rate for each test, these results were obtained: the outflow rate at a constant hydraulic gradient had a decreasing trend in time. The reason was probably the movement of the fine soil particles into micro pores and also envelopes (if existed) because of water flow pressure which eventually resulted in the hydraulic conductivity reduction. Figure 5 shows the variations of the soil hydraulic conductivity (in system without envelope) and the hydraulic conductivity of the soil-envelope systems (in systems with envelope). It

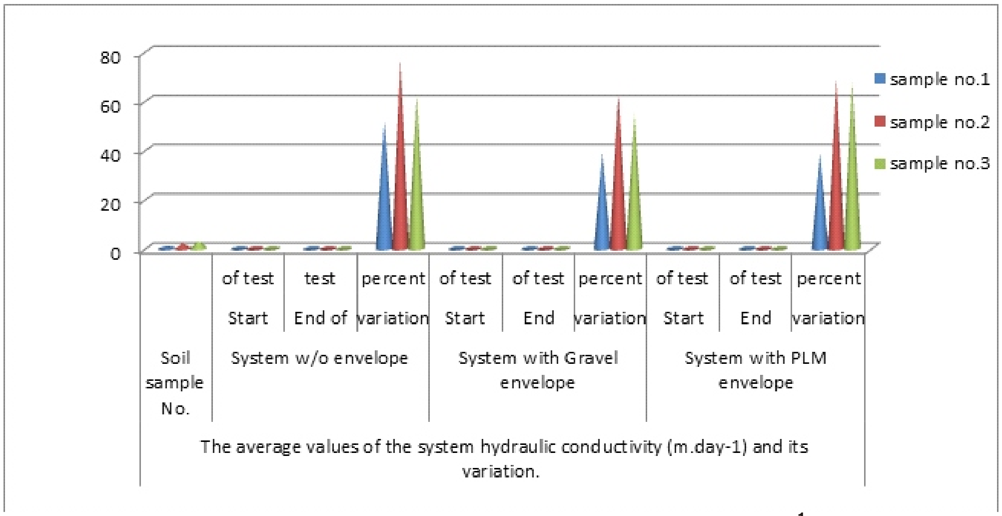

Figure-5 : Average values of the system hydraulic conductivity (m. day^{-1}) and its variation.

can be seen that any increase in the hydraulic gradient resulted in a reduction in the values of the hydraulic conductivity. But, since the pressure of the water flow increased, the outflow rate showed an increasing trend. The outflow rates of the system with mineral envelope were always greater than the rates of the other systems. The main reason was high hydraulic radius (because of envelope hydraulic functions) and therefore, the hydraulic ease of the inflow into the drains.

The ratio between the outflow rates from system with mineral envelope to the system without envelope in samples No. 1, 2 and 3 were 2.7, 3.4 and 2.6, respectively. Also, this ratio for the system with synthetic envelope and the system without envelope were 1.7, 1.4 and 1.8, respectively. The variations of the outflow rate vs. the system hydraulic gradient values. The results showed that the differences between the outflow rates of the systems with synthetic envelope and without envelope was negligible in sample No.2. The higher values of SAR in this sample caused the dispersion of soil particles and reduction of the hydraulic conductivity. On the other hand, the amount of the envelope clogging was more in this situation. Moreover, when the hydraulic gradient of the system exceeded 5, the permeability decreased substantially in this sample in a way that the outflow rate hardly changed and then after the hydraulic gradient exceeded 7.5, soil particles movement from the drain plate openings happened. The reduction of the outflow rate in the system with mineral envelope was less than the system with synthetic envelope and the outflow rates were 2-3 times more at all the gradient values. This indicates the higher hydraulic conductivity of the mineral envelope as compared to the synthetic envelope. The differences between the outflow rates of the system without envelope and the systems with envelope were lower at the hydraulic gradients less than 5 and were higher at the hydraulic gradients of 10 and more. In the other words, the hydraulic role of the envelope is more remarkable at higher gradients.

Gradient Ratio Index : A gradient index was used to assess the clogging potential of the soil cover system. In addition, this index was used to analyze the clogging potential of the system without a envelop, as changes in the shape of the flow lines in the sewer and an increase in pressure drop at the sewer plate increase the clogging potential in the lower part of the system. Gradient coefficient values ??less than one indicate a higher hydraulic conductivity of the soil winding system at the gutter plate than a hydraulic conductivity of the soil. Conversely, values ??greater than one indicate the potential for clogging. In almost all tests, the values ??of the gradient ratio increased as the hydraulic gradient of the system increased. The highest values ??of this index in all samples occurred in the system without an envelope. In addition, several variations have taken place in this system. The reason was the movement of fine soil particles onto the drainage plate and also into the macro pores. These particles could not pass through the openings and eventually caused clogging of the openings and increased the input resistance. In envelope systems, these particles were able to find their way outwards, and therefore a smaller pressure drop was measured in this part. Gradient index values ??in the mineral-coated system were lower for samples n. 1 and 3 for sample No 2. In sample no. 2, when the hydraulic slopes have exceeded 5, the values ??of this index are calculated more than 1, which indicates a higher risk of clogging of the sample. However, the mineral shell performed better in all samples. In addition, in the synthetic coating system, the values ??of the gradient ratio were less than one in almost all soil samples. According to the test results of this study, a serious risk of clogging occurs if the gradient ratio

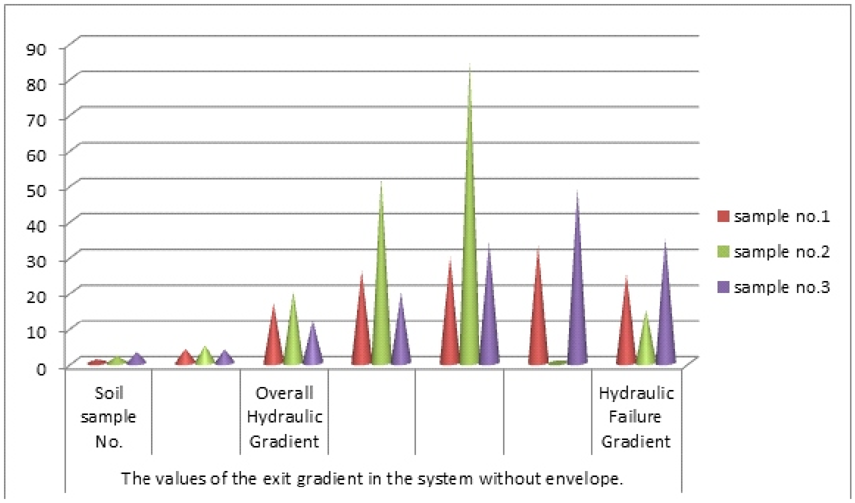

Figure-6 : the values of the exit gradient in the system without envelope.

exceeds 3. Only in sample no. 2, the values ??of the gradient ratio were more than 3, and there was a potential for soil particles to move in the pipe sewer.

Exit Gradient : In Figure 6 the values of the exit gradient for the system without envelope and at all the gradient values. In all three soil samples, the exit gradient increased by the increase of the system hydraulic gradient. The lower value of SAR besides high salinity of sample No.1 decreased the soil dispersion and the exit gradient. Although because of the lower clay percent, the failure gradient was also low and this increased the potential of soil particle movement into drain pipe at the gradients of 7.5 to 10. In sample No.2, substantial increase of the exit gradient and also the lower value of the failure gradient occurred. These were because of the lower clay percent which caused a critical condition in a way that the system without envelope had an acceptable performance just at the gradients of 1 and 2.5. The high amount of plasticity in sample No.3 was the main reasons for the acceptable performance of the system without envelope in this sample since the danger of soil particle movement into drainpipe existed only at the gradient of 10. The systems with mineral and synthetic envelopes showed lower values of the exit gradient which were lower than the failure gradient in all the tests.

Conclusions

The system without envelope had a better performance in sample No.3 and the danger of soil particle movement into drain pipe existed only at the gradient of 10. In this sample, despite of the high values of SAR (more than 12), the performance of the system without envelope was acceptable and it seems that the suggested criteria in the method of clay percent and the value of SAR is more cautious. In sample No. 1, in spite of the positive effect of salinity, the lower amount of plasticity caused the more transfer of the soilparticles towards the drain plate and therefore, the head loss in the exit part increased. In sample No. 2, the high values of SAR was the main reason of the lower performance of the system without envelope and the critical condition existed at the gradients of more than 5. By the increase of the clay percent, the difference between the performance of the systems with and without envelope decreased. With a constant amount of clay, the less silt percent caused the less potential of drain pipe clogging. The performance of thesystems without envelope in the soils with the clay percent of more than 35 and the PI values of more than 12 may be acceptable providing the proper chemical properties of water exists (SAR less than 25).

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