CHEMICAL PROPERTIES OF SALT AFFECTED SOIL AND YIELD OF SUGARCANE IN RELATION TO WATER TABLE DEPTHS IN MARDAN SCARP AREA

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ABSTRACT

A field experiment was carried out to study the impact of different water table depths (WTD) on the chemical properties of soil and yield of sugarcane in Mardan SCARP area from September, 2000 to May, 2001. Five drainage units such as 106, 107, 108, 122 and 129 were selected in which observation wells were installed to monitor the water table depths. Soil samples from 0-30 cm depth were collected for the chemical analysis of electrical conductivity (Ec), sodium adsorption ratio (SAR) and soil reaction (pH). All the required data were collected at the head (H), middle (M) and tail (T) of the selected collectors in each drainage unit. The average WTD of drainage units 106, 108 (farmers’ controlled collectors), 122 (badly managed blocked collector), 107, and 129 (well managed free flowing collectors) were 1.67, 1.53, 1.16, 2.17 and 1.9 m, respectively from the ground surface. There was a rising trend in WTD at the tail of the blocked collectors. The average WTD of free flowing drainage units were relatively deeper than blocked ones. The average Ec, SAR and pH were in the range of 0.73–2.3 dS m⁻¹, 1.2–8.2 and 6.96–9.13, respectively in the selected drainage units. The Ec, pH and SAR were highest in the badly managed blocked drainage unit, while EC, and pH were lowest in free flowing drainage units. Average yield of sugarcane in all the above mentioned drainage units were in the range of 36.99–52.00 t ha⁻¹ and was highest in one of the farmer’s blocked drainage unit and lowest in badly managed blocked drainage unit. The yield of sugarcane was optimum at a WTD of 1.2-1.9 m and lowest at <1 m or >2 m from the ground surface. The overall results indicated that an optimum sugarcane yield can be obtained in Mardan SCARP area by maintaining water table from ground surface in the range of 1.2–1.9 m.

Key Words: EC, Mardan SCARP, pH, SAR, Sugarcane Yield, WTD

INTRODUCTION

The government of Pakistan started salinity control and reclamation projects (SCARP) in different parts of the country to lower the water table and to reclaim the irrigated saline waste area into productive ones. Initially vertical drainage system was introduced and about 13,000 deep tube wells were installed in Pakistan. But later on due to high operational and maintenance cost, as well as wear and tear problem with the tube wells, a horizontal subsurface tile drainage system was therefore, preferred over vertical drainage system. In the irrigated area of Mardan SCARP such type of subsurface drainage system was installed. It encompasses 50,000 hectares of 54,500 total cultivable command area of the lower swat irrigation canal. After implementation of the project water table got much lower than the design one (1.1 m) in some areas, which created two main problems i.e. high water demand and attack of termites on crops. To overcome these problems, few farmers have controlled the main collectors in a struggle to raise the water table for maximum ground water contribution to the crop water requirements. Thus, they intervened in the already implemented system of SCARP.

Indigenous work indicated that the yield in the non-waterlogged area was double as compared to the waterlogged conditions (Kakar, 2000). Similarly, Khan et al. (1997) also compared the yield of sugarcane before and after the Mardan SCARP implementation, which was 33.96 and 58.26 t ha⁻¹, respectively. Gupta and Yadav (1995) also reported that sugarcane yield was significantly decreased at a depth of 20 cm below the surface. The farmer based subsurface controlled drainage decision and its impact on the estimation of chemical parameters are helpful for crop grown, leaching requirement and intervention that could be taken for further improvement of soil.
and maximum production per unit amount of water and land holding. As Kahlown and Iqbal (1999) reported that a water table depth of greater than 2 m was found more favorable for cotton, 1 to 2 m for wheat and sugarcane, and less than 1 m for rice. Moreover, Asim (1999), Khan (1999) and Bhutta et al. (1996) concluded that tile drainage system was working well in decreasing soil salinity of root zone, increasing crop yield and reducing standing water problem. Therefore, the present study was designed to assess the impact of different water table depths as influenced by the farmer’s intervention and maintenance status of the selected plans, in relation to some chemical properties of salt affected soil such as EC, pH and SAR and movement of water into and through the soil profile and yield of sugarcane crop.

MATERIALS AND METHODS

Site Selection
Sub-surface tile drainage system at Mardan-Pakistan SCARP was installed from 1982-1987 in contract I area and from 1987–1992, in contract II area of Mardan. Contract I area consists of 36 drainage plans (101-136), whereas contract II area consists of 88 drainage plans (200-250 and 300-338). The contract I area had shallow water table depth (0-1.22 m) before implementation of the sub-surface drainage system as compared to contract II area having deeper water table depth (1.22–2.13 m). The contract I was further divided into two sub-groups of water table. The first part was mostly abandoned while the second one was still on optimum in terms of multi cropped growth and yield. In order to analyze the chemical properties along with yield of sugarcane at different water table depths in plans 106, 107, 108, 122 and 129. Plans 106 and 108 have been selected from the area controlled by the farmers with a view to raise the water table in their fields for maximum ground water contribution. Plans 107 and 129 had well managed open collectors, while the collector of plan 122 was partially closed due to badly managed poor conditions of the open drain.

Determination of Chemical Properties
The required chemical properties included determination of electrical conductivity (EC), sodium adsorption ratio (SAR) and soil pH at 0-30 cm depth of soil at head (H), middle (M) and tail (T) of the selected collector in each plan.

Electrical Conductivity (EC)
Electrical conductivity measurements were made to estimate the soluble salts in the saturated extract of soil with the help of electrical conductivity meter (Rhoades, 1982).

Sodium Adsorption Ratio (SAR)
After determination of each cation such as Na, Ca and Mg in soil, the SAR was calculated using the following formula (Richards, 1954).

\[
SAR = \frac{Na}{\sqrt{Ca + Mg}}
\]

Soil pH
The pH of soil suspension (1:5) was prepared for each soil sample and was determined by pH meter (McLean, 1982)

Sugarcane Yield
The yield data for sugarcane crop was collected at the head (H), middle (M) and tail (T) of each area in the experimental site.

Statistical Analysis
The entire data for each parameter was subjected to correlation and regression, using a computer program Microsoft Excel (Steel et al., 1997).

RESULTS AND DISCUSSION

Effect of Farmers’ Intervention Status on WTD
Observation wells were installed at the head (H), middle (M) and tail (T) of the selected collector in all five plans such as 106, 108, 107, 129 and 122. In the plans 106 and 108 collectors were controlled by the farmers with a view to raise water level in their fields for maximum ground water contribution to the crop water requirements.
Plans 107 and 129 had well-managed open collectors, while the collector of plan number 122 was blocked due to badly managed poor conditions of the open drain. The trend in change of WTD at various selected locations in the plans is shown in Fig. 1.

![Fig. 1 WTD in the selected plans](image)

Plans 106, 108 and 122 showed similar trend of change in WTD. However, here the WTD is lowest from the ground surface at the middle and highest at the tail of collector. The reason is that the collectors in these plans were blocked and were discharging no or very little amount of water to the open drain. Water drained from the middle and head accumulated at the tail portion of collector. This resulted in rise of water level at the tail. The water level at head was closed to ground surface than at middle for the obvious reason of seepage from canals. The plans 107 and 129, well managed open collectors, showed similar trend in change of WTD at the head, middle and tail of collector. In theses plans water level is going on deeper and deeper along the collector from head towards the tail. Because, the water table is highest at the head of the collector due to seepage from the canal and lowest at the tail due to deep open drain.

**WTD and Soil Salinity**

Results showed salinity status of the soil at head (H), middle (M) and tail (T) of the selected collectors in all the five plans. Table I shows that soil salinity increased with rising in water level. Plan number 122 has highest salinity with an average value of 2.3 dS m$^{-1}$ at the highest average water level of 1.16 m, where as plan number 107 has lowest average salinity value of 0.73 dS m$^{-1}$ with relatively deep water table of 2.17 m in all the selected plans. The plans 106, 108 and 129 have average salinity values of 1.9, 1.85 and 1.48 dS m$^{-1}$ at average WTD of 1.67, 1.53 and 1.9 m, respectively. These results are supported by the previous work of Asim (1999). Moreover, the salinity values were highest at the tail of blocked plans and lowest at the middle due to difference in WTD. Whereas the tail of the plans 107 and 129 (free drainage) the salinity was the lowest due to relatively deep water table.

<table>
<thead>
<tr>
<th>Plans</th>
<th>WTD (m)</th>
<th>EC$_e$ (dS m$^{-1}$)</th>
<th>SAR</th>
<th>pH</th>
<th>Yield (t ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>122-H</td>
<td>1.10</td>
<td>2.30</td>
<td>8.5</td>
<td>9.0</td>
<td>34.34</td>
</tr>
<tr>
<td>122-M</td>
<td>1.50</td>
<td>2.20</td>
<td>7.0</td>
<td>8.9</td>
<td>44.65</td>
</tr>
<tr>
<td>122-T</td>
<td>0.90</td>
<td>2.50</td>
<td>9.0</td>
<td>9.5</td>
<td>31.98</td>
</tr>
<tr>
<td>106-H</td>
<td>1.90</td>
<td>1.90</td>
<td>1.5</td>
<td>7.7</td>
<td>40.26</td>
</tr>
<tr>
<td>106-M</td>
<td>2.10</td>
<td>1.80</td>
<td>3.5</td>
<td>7.6</td>
<td>39.00</td>
</tr>
<tr>
<td>106-T</td>
<td>1.02</td>
<td>2.00</td>
<td>3.5</td>
<td>6.8</td>
<td>41.45</td>
</tr>
<tr>
<td>108-H</td>
<td>1.60</td>
<td>2.00</td>
<td>1.2</td>
<td>7.6</td>
<td>53.23</td>
</tr>
<tr>
<td>108-M</td>
<td>1.80</td>
<td>1.65</td>
<td>1.2</td>
<td>7.5</td>
<td>52.12</td>
</tr>
<tr>
<td>108-T</td>
<td>1.20</td>
<td>1.90</td>
<td>1.1</td>
<td>7.5</td>
<td>50.65</td>
</tr>
<tr>
<td>129-H</td>
<td>1.50</td>
<td>1.60</td>
<td>4.0</td>
<td>7.1</td>
<td>53.00</td>
</tr>
<tr>
<td>129-M</td>
<td>1.90</td>
<td>1.45</td>
<td>1.0</td>
<td>7.0</td>
<td>52.32</td>
</tr>
<tr>
<td>129-T</td>
<td>2.30</td>
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<td>2.7</td>
<td>7.1</td>
<td>39.20</td>
</tr>
<tr>
<td>107-H</td>
<td>1.50</td>
<td>1.30</td>
<td>2.4</td>
<td>7.1</td>
<td>49.24</td>
</tr>
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<td>107-M</td>
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<td>0.60</td>
<td>2.1</td>
<td>7.0</td>
<td>43.00</td>
</tr>
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<td>107-T</td>
<td>2.70</td>
<td>0.30</td>
<td>2.8</td>
<td>6.8</td>
<td>41.54</td>
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</table>
The overall relationship of electrical conductivity with WTD in all plans is demonstrated in Fig. 2. Results showed that there is a significant correlation between WTD and soil salinity at 5% level of significance, under the assumption that there is no other factor affecting these two. Fig. 2 also shows increasing trend in soil salinity with the rising in water table and vice versa. These results are supported by the previous work of Asim (1999).

\[ y = -0.9333x + 3.2355 \]
\[ R^2 = 0.665 \]

**Fig. 2 Relationship between Ec and WTD (0-30 cm) of soil in the selected plans**

**WTD and Soil Sodicity**

Results showed that SAR is highest in plan number 122 with an average value of 8.2 and lowest in plan number 108 with an average value of 1.2 (Table I). The average SAR value of plans 106, 129 and 107 are 2.8, 2.5 and 2.4, respectively. It suggests that both well-managed open plans have lowest SAR value for the obvious reason of proper drainage. Similar results were reported by Asim (1999). The cause of lowest SAR value in plan number 108 was that of good soil condition due to high natural gradient between main irrigation and drainage systems, providing efficient field surface drainage. Where as the plan number 122 had the highest SAR value for the apparent reasons of poor surface and subsurface drainage, poor soil conditions with alkalinity problem and no use of gypsum.

Fig. 3 depicts the overall relationship of SAR at 0-30 cm depth of soil with WTD in the selected plans. The relationship shows that there was no significant correlation between WTD and SAR of the soil at 5% level of significance. However, there exists an increasing trend of SAR values with rising water table and vice versa. Similar results were reported by Asim (1999) and Sarwar et al. (2002).

\[ y = -2.5489x + 7.7359 \]
\[ R^2 = 0.2511 \]

**Fig. 3 Relationship between SAR and WTD (0-30 cm) of soil in the selected plans**

**WTD and Soil pH**

Results showed changes in soil pH with WTD at the selected plans (Table I). The plan number 122 has highest pH with an average value of 9.13 whereas plan number 107 has lowest average pH value of 6.96 with comparatively highest WTD. Plans 106, 108 and 129 have average pH values of 7.37, 7.5 and 7.07, respectively.
The high pH values imbalance the solubility of various ions and influences the biological activities (Song and Ishiquro, 1990). However, from crop production point of view pH in the range of 7.76-8.46 does not strongly affect the availability of macronutrients (N, P and K), though soil pH between 5 and 7.5 is preferred by most of the agricultural crops (Tisdale et al., 1985). Therefore, in the present situation no need of any kind of special treatment to any of the plans, except plan number 122 for the balanced nutrients availability to the crops.

The Fig. 4 shows a significant correlation between WTD and soil pH at 5% level of significance. Results indicate that as the pH of soil increased with rising water level and vice versa, showed improvement of soil pH by installation of drainage system in the water logged areas. These results are in agreement with the findings of Kakar (2000) and Asim (1999).

\[ y = -0.8907x + 9.1168 \]
\[ R^2 = 0.3011 \]

**Fig. 4 Relationship between soil pH and WTD (0-30 cm) of soil in the selected plans**

**WTD and Yield of Sugarcane**

The impact of different WTD ranges on the yield of sugarcane has been studied in general and specifically for the selected plans (Table 1). The drainage unit 122 (badly managed) has average sugarcane yield of 36.99 t ha\(^{-1}\), at an average WTD of 1.16 m. Here, the yield was lowest at tail (31.98 t ha\(^{-1}\)) of the collector due to the shallow WTD of 0.9 m, highest EC, SAR, pH, of all the plans. The yield was relatively high having 44.65 t ha\(^{-1}\), though EC, SAR and pH values are appreciably high, but still within the safe limit at middle of the plan number 122. The cause of good yield at this location could be due to suitable WTD for the crop that result in high ground water contribution to crop water requirements. Drainage unit 108 (controlled by the farmer) had remarkable yield of 52.00 t ha\(^{-1}\) at an average WTD of 1.53 m. In this drainage unit the WTD was in the best suitable range at all locations of the drainage unit and hence maximum ground water contribution to the crop water requirements was ultimately observed. Moreover, the other factors such as EC, SAR and pH were also within the safe limits in this plan. Plan number 106 has relatively higher values of yield at tail and middle than at head for more or less the same above mentioned reasons. Drainage unit 129 (well-managed open drainage unit) has its highest yield of 53.00 and 52.32 t ha\(^{-1}\) at head and middle portion, respectively. The reason was maximum ground water contribution for the crop water requirement from the suitable WTD level in the fields. In plan number 107 (open collector) yield of sugarcane was highest at head with an average value of 49.24 t ha\(^{-1}\) at a WTD of 1.5 m. The yield of the same drainage unit decreased at the middle and tail portion due to lowering of WTD from the surface. Here, the average yield at middle and tail was 43.00 and 41.54 t ha\(^{-1}\) at 2.3 and 2.7 m WTD, respectively. The farmers at tail had a complaint of water shortage to their crop. They also had a complaint of white ants in their fields (From a blocked interview with farmers).

Fig. 5 depicts the overall relationship of sugarcane yield with WTD. It is evident from the graph that the yield of sugarcane was the highest between the range of 1.2-1.9 m and the lowest at a WTD of less than 1 m. Similarly, there was a decreasing trend of crop yield when WTD increased beyond 2 m. These results are closed to the findings of Kahlown and Iqbal (1999). On the basis of present results, it can be said that sugarcane crop need a suitable range of WTD, for high ground water contribution to the crop water requirements and yield.
CONCLUSION
It can be concluded from the present study that soil salinity and pH increased with shallow WTD. There was 68 and 24% increase in soil salinity and pH respectively, when WTD rose from 2.17 (WTD of well managed free flowing drainage unit) to 1.16 m (WTD of badly managed drainage unit). The SAR value was 85% more in badly managed blocked drainage unit than farmer’s closed drainage unit. Sugarcane yield was optimum at WTD of 1.2-1.9 m and lowest at WTD <1 m or >2 m.

REFERENCES