# AN INSIGHT INTO PROMINENT SOIL CHARACTERS OF SARGODHA AREAS FOR THE ESTABLISHMENT OF HEALTHY CITRUS ORCHARDS

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## ABSTRACT

**In this study soil EC and pH contributing to citrus fruit quality were studied in Sargodha, Punjab, Pakistan during 2006-08. For this purpose an elaborated survey of the area was made and 743 soil samples were collected from 41 locations of citrus growing areas of Sargodha district upto the depth of 0-5, 15-30, 30-60, 60-90, 90-120 and 120-150 cm. Analysis of data produced distinctive results relating to EC/pH of the large areas (Sargodh, Bhalwal, Shahpur, Silanwali, Kotmomin and Sahiwal). The results revealed that 71.2 percent of total samples had ≤ 2dS/m EC and 42.6 percent of the samples had pH ≤ 8.2 being safe ranges of EC and pH of citrus. According to classification of salt affected soils, 59.4 percent of total soils were normal and remaining 40.6 percent were salt affected (3.9% saline, 7.8% saline sodic and 28.9% sodic). The study confirmed the concern of citrus scientists that soil factors particularly pH and EC in Sargodha areas are increasing unfavorable conditions which hinder healthy and productive substance of citrus orchards. The present research was undertaken first time to provide a clear insight about soil related factors responsible for uneconomic life span, reduced yields and poor fruit quality.**

**KEYWORDS: Citrus; orchards; soil physicochemical properties; Sargodha; Pakistan.**

## INTRODUCTION

The problem of salinity/alkalinity exists on smaller or greater scale practically in many localities. About seven million hectares are salt affected area in Pakistan. It is mainly due to scarcity of good quality irrigation water and use of brackish water. Shortage of good quality water and low and variable rainfall pattern compel the farmers to use brackish water for irrigation (13). Successful and sustainable agriculture, especially in irrigated dry region,

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mostly depends upon the salt and water balance. Positive salt balance promotes the formation of salt affected soils while negative salt balance induces desalinization/desodication.

In Pakistan, the problem has been further aggravated by inefficient use of irrigation water, inadequate water supplies, poor soil management and inadequate drainage. Salt loaded irrigation waters are direct sources of salt on good quality lands. On an average, ground water contains 1250 mg salts per hectare. An irrigation of 10 cm with such water will add 1.2 Mg salts per hectare. Mostly irrigation waters in arid region are mineralized; as a result of capillary effect, water continuously rises upward and enriches the soil surface with salts following evaporation. It is major cause of development of salty land in irrigated areas. Unevenness of field results in differential percolation of water (rate and quantity) and after some years, it helps in the emergence of patchy salinity followed by sodicity (3). In saline soil Na occurs with $Cl^{-1}$ and $SO_4^{-1}$ whereas in sodic soils Na occurs with $CO_3$ and $HCO_3$. Low yield of crops due to saline and sodic soils is associated with increased uptake of Na and decreased uptake of K (lower K/Na ratio). Higher concentration of Na in leaves is associated with decreased rate of photosynthesis and respiration (9).

The pH value of 5.5 to 6.0 (acidic) is considered to be an optimum for citrus cultivation; as the lower level tends to increase leaching of lime and magnesium whereas higher level is conducive to reduce the availability of trace elements. Nevertheless, citrus orchards continue to flourish on a wide variety of soil having pH from 4.0 to 8.5 or even higher. Citrus health is adversely affected and succumbs to various problems as a result of malnutrition, due to excessive salts in soil (10). Therefore, the total concentration of salts in soil should not exceed 1000 ppm (EC 1.33 dS/m). The presence of excessive salts in any horizon upto the depth of 180 cm adversely affects the health of citrus plants (11). However, higher pH not only affects the availability of micronutrients but high Na contents of such soils may have toxic effects in case of sensitive crop like citrus. The nutrients become more available at 7.0 pH value. Most of the soils in Pakistan are calcareous in nature, having pH 7.5-8.5. At this range, nutrient like Cu, Mn, Fe and B are immobilized due to their precipitation and their adsorption on $CaCO_3$ particles (6). Contrary to other agronomic and horticultural crops, citrus species are among the most sensitive to soil salinity (7).

Soils with more than 1000 ppm total salts should be avoided for citrus production (15). Salts in soil solution exert an osmotic pressure measured by

osmotic potential that reduce the availability of free (unbound) water through both chemical and physical processes. Roots are, therefore, not able to extract as much water from the solution that is high in salts than from low in salts (16).

A decrease in water absorption under saline soil condition compels plant to expend more and more metabolic energy to absorb water at the cost of growth. Thus at any given soil moisture level, presence of salts increases the energy requirements of the plants to maintain cell turgor. If a plant does not meet such energy demands, water uptake and transpiration are reduced which adversely affect plant growth and yield (4). A decrease of 11.2 kg fruit per tree occurs with each dS/m increase in EC. Threshold level of salinity for oranges is 1.7 dS/m and 50 percent yield reduction occurs at an EC of 4.8 dS/m (14). Yield of grape fruit, orange and lemon decreases 10-20 percent at EC levels 3.5, 3.0, and 2.5 dS/m, respectively (7). Citrus thrives better in the deep loose, well aerated soils devoid of any hard pan layer of calcium carbonate in rooting zone. Ideal soil pH for citrus is considered to be 5.5- 7.5 but majority of the soils in Sargodha district possess pH 8.0- 8.8 (2).

Number of factors affect citrus yield and quality but soil pH and EC directly or indirectly affect citrus yield and quality. So the present study was planned to evaluate these soil characters for successful citrus production in Sargodha district.

## MATERIALS AND METHODS

This study was carried out at Citrus Research Institute, Sargodha, Pakistan during 2006-2008.Seven hundred and forty three soil samples were collected from 41 locations of citrus growing areas in Sargodha district. The soil samples were collected upto the depth of 0-15, 15-30, 30-60, 60-90, 90-120 and 120-150 cm. These samples were air dried and prepared for the analysis. After preparation, their suspension of 1:10 (soil:water) was prepared and electrical conductivity of each sample was measured through a conductivity meter. The ECe was calculated with the help of following formula (1).

$$ECe = \frac{\text{Measured EC} \times \text{d.f.(dilution factor)}}{1.33}$$

The pH of saturated soil paste was measured through pH meter, after the over night stay of soil paste according to method described by Updhayay and Sharma (17).

## RESULTS AND DISCUSSION

### Soil EC

The soil EC of citrus growing areas in Sargodha district ranged between 0.5-24.5 thereby giving an average of 2.18 dS/m (Tabel 1). It was above the required level (< 2 dS/m) to harvest 100 percent citrus yield potential as prescribed by previous workers (4, 10, 15). Only 10.9 percent of soil samples had EC >4 dS/m (Table)

**Table 1. Soil EC of citrus growing areas of Sargodha district.**

| Name of tehsils | Total No. of samples | EC (dS/m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Range | Average | < 4 | | > 4 | |
| | | | | No. of Samples | Per-cent | No. of samples | Per-cent |
| Sargodha | 211 | 0.8-10.8 | 2.06 | 188 | 89.1 | 23 | 10.9 |
| Sahiwal | 112 | 0.9-20.5 | 2.56 | 94 | 83.9 | 18 | 16.1 |
| Silanwali | 114 | 0.5-7.3 | 1.44 | 109 | 95.6 | 5 | 4.4 |
| Shahpur | 139 | 0.8-24.5 | 2.73 | 105 | 75.5 | 34 | 24.5 |
| Bhalwal | 84 | 0.5-5.5 | 2.33 | 78 | 92.8 | 6 | 7.1 |
| Kotmomin | 83 | 0.5-4.2 | 1.89 | 83 | 100 | 1 | 0 |
| Whole district | 743 | 0.5-24.5 | 2.18 | 662 | 89.1 | 81 | 10.9 |

### Soil pH

The soil pH in Sargodha district ranged between 7.8-10.4 with an average of 8.42 (Table 3). Sixty three percent samples had pH < 8.5 which may be considered as normal soil (Table 3). Thirty seven percent soil samples had pH>8.5.

**Table 2. Tehsil-wise pH of Sargodha district.**

| Name of tehsils | Total No. of samples | pH | | | | | |
|---|---|---|---|---|---|---|---|
| | | Range | Average | <8.5 | | >8.5 | |
| | | | | No. of samples | Per-cent | No. of samples | Per-cent |
| Sargodha | 211 | 7.8-9.3 | 8.21 | 181 | 85.8 | 30 | 14.2 |
| Sahiwal | 112 | 7.9-10.4 | 8.78 | 41 | 36.7 | 71 | 63.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Silanwali | 114 | 7.8-9.3 | 8.46 | 57 | 50.0 | 57 | 50.0 |
| Shahpur | 139 | 8.0-9.8 | 8.56 | 75 | 54.0 | 64 | 46.0 |
| Bhalwal | 84 | 7.9-9.4 | 8.16 | 70 | 83.3 | 14 | 16.7 |
| Kotmomin | 83 | 7.9-9.1 | 8.44 | 44 | 53.0 | 39 | 47.0 |
| Whole district | 743 | 7.8-10.4 | 8.42 | 468 | 63.0 | 275 | 37.0 |

## Classification of soil samples

The results indicated that 59.4 percent of total soil samples in Sargodha district were normal and remaining 40.6 percent were salt affected (3.9% saline, 7.8% saline sodic and 28.9% sodic) (Table 3). Maximum number of salt affected soil samples were observed in tehsil Sahiwal (47.3+16.1=63.4%) followed by tehsil Shahpur (53.3 %) and tehsil Silanwali (50%).

The data (Table 3) further revealed that majority of salt affected soil samples (28.9 %) were sodic in nature. With the increase in soil pH and salt concentration due to evaporation, a part of calcium and magnesium in soil solution precipitates as calcium carbonate and magnesium silicate.

**Table 3. Classification of salt affected soils of citrus growing areas according to US. Lab. Staff, 1954.**

| Tehsils | Total samples | Normal | | Saline | | Saline Sodic | | Sodic | |
|---|---|---|---|---|---|---|---|---|---|
| | | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % |
| **Sargodha** | **211** | **167** | **79.1** | **14** | **6.6** | **9** | **4.3** | **21** | **10.0** |
| **Sahiwal** | **112** | **41** | **36.6** | **0** | **0** | **18** | **16.1** | **53** | **47.3** |
| **Sillanwali** | **114** | **57** | **50** | **0** | **0** | **5** | **4.4** | **52** | **45.6** |
| **Shahpur** | **139** | **65** | **46.8** | **10** | **7.2** | **24** | **17.3** | **40** | **28.8** |
| **Bhalwal** | **84** | **67** | **79.8** | **4** | **4.7** | **2** | **2.4** | **11** | **13.1** |
| **Kotmomin** | **83** | **44** | **53.0** | **1** | **1.2** | **0** | **0** | **38** | **45.8** |
| **Whole district** | **743** | **441** | **59.4** | **29** | **3.9** | **59** | **7.8** | **215** | **28.9** |
| **Criteria used for classification according to US.Lab.Staff, 1954.** | | | | | | | | | |
| **Type of soil** | | **Normal soil** | | **Saline** | | **Saline sodic** | | **Sodic** | |
| **pH** | | **<8.5** | | **<8.5** | | **>8.5** | | **>8.5** | |
| **EC (dS/m)** | | **<4** | | **>4** | | **>4** | | **<4** | |

The precipitation of these sparingly soluble salts increases the proportion of sodium in soil solution and consequently on soil exchange complex. Thus saline soils serve as parent material for the formation of sodic soils. In other words, sodication many times follows salination (2). As a proportion of exchangeable sodium increases in the soils, the breakdown of soil structure is promoted which results in greatly decreased entry of air and water into the soils, which further results in marked increase in hydraulic conductivity (8). Dispersion also results in the formation of dense impermeable surface crust

which hinders seedling emergence, root growth and thus decrease plant population.

## Influence of soil pH and EC hazards on citrus yield potential

***Soil EC:*** The soil samples were categorized into four classes on the basis of EC (Table 4). The results depicted that 71.2 percent soil samples had ≥2 dS/m, while 17.9 percent soil samples fell in the range 2.1- 4.0 dS/m, 7.7 percent soil samples ranged from 4.1- 6.4 dS/m and 3.2 percent exceeded the limit of 6.5 dS/m where citrus yield can be expected upto 100, 75, 50 and 0 percent, respectively.

**Table 4. Soil EC (dS/m) of citrus growing areas in Sargodha district.**

| | Total. No. of samples | <2 | | 2.1- 4 | | 4.1- 6.4 | | > 6.5 | |
|---|---|---|---|---|---|---|---|---|---|
| | | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % |
| Sargodha | 211 | 176 | 83.4 | 12 | 5.7 | 15 | 7.1 | 8 | 3.8 |
| Sahiwal | 112 | 62 | 55.4 | 32 | 28.6 | 7 | 6.2 | 11 | 9.8 |
| Silanwali | 114 | 91 | 79.8 | 18 | 15.8 | 5 | 4.4 | 0 | 0 |
| Shahpur | 139 | 73 | 52.5 | 37 | 26.6 | 24 | 17.3 | 5 | 3.6 |
| Bhalwal | 84 | 68 | 80.9 | 10 | 11.9 | 6 | 7.1 | 0 | 0 |
| Kotmomin | 83 | 59 | 71.1 | 24 | 28.9 | 0 | 0 | 0 | 0 |
| WholeDistrict | 743 | 529 | 71.2 | 133 | 17.9 | 57 | 7.7 | 24 | 3.2 |

Salt tolerance and yield potential of citrus as influenced by EC (4)

| Crop | 100 % | 75 % | 50 % | 0 % |
|---|---|---|---|---|
| Grape fruit | 1.8 | 3.3 | 4.8 | >8 |
| Orange | 1.7 | 2.9 | 4.1 | >6.5 |

The present results support the findings of earlier workers (4, 7, 12, 14, 15) who have described that citrus is highly susceptible to soil salinity. Higher concentrations of Na in leaves are associated with decreased rate of photosynthesis and respiration. The presence of excessive salts in any horizon upto the depth of 180 cm adversely affects the health of citrus plants. Reduction in fruit yield per plant caused by salt stress is primarily due to decrease in number of fruits per tree rather than decrease in fruit weight.

***Soil pH:*** Soil samples were divided into six categories on the basis of ill effects of soil pH on citrus plants (Table 5). Only 42.6 percent (19.8+22.8) soil samples had pH ≤ 8.2 (able to support optimum citrus plant health and fruit yield). These findings are supported by different workers (2, 6, 9) who described that availability of majority of nutrients becomes more at pH around 7. Most of the soils in Pakistan are calcareous in nature with pH 8. At

this pH, availability of P, K, Zn, Cu, Fe, Mn, B, etc. is decreased due to immobilization, precipitation and adsorption on $CaCO_3$ particles.

The data (Table 6) indicated that out of 163 points 84 points (51.15 %) upto 30 cm depth, had soil pH ≤8.2 and EC ≤ 2 dS/m and out of 118 points 34 points (25.18 %) had soil pH ≤8.2 and EC ≤ 2 dS/m with no layer of excessive salts. These levels of pH and EC are considered to give 100 percent citrus yield potential. Rajput and Haribau (10) and Ghafoor *et al*. (3, 4, 5) also proposed that no layer of soil upto the depth of 180 cm should have excessive salts (pH 8 and EC 2 dS/m).

Table 5. Soil pH of citrus growing areas in Sargodha district and levels of sodicity hazards on citrus plants.

| Tehsils | Total. No. of samples | <8.0 | | 8.0-8.2 | | 8.3-8.4 | | 8.5.8.6 | | 8.6-8.8 | | >8.8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % |
| Sargodha | 211 | 25 | 11.8 | 123 | 58.3 | 33 | 15.6 | 13 | 6.2 | 8 | 3.8 | 9 | 4.3 |
| Sahiwal | 112 | 1 | 0.9 | 15 | 13.4 | 25 | 22.3 | 19 | 17.0 | 13 | 11.6 | 39 | 34.8 |
| Silanwalli | 114 | 16 | 14.0 | 25 | 21.9 | 16 | 14.0 | 21 | 18.4 | 19 | 16.7 | 17 | 14.9 |
| Shahpur | 139 | 9 | 6.5 | 29 | 20.9 | 37 | 26.6 | 23 | 16.6 | 10 | 7.2 | 31 | 22.3 |
| Bhalwal | 84 | 21 | 25.0 | 29 | 34.5 | 20 | 23.8 | 11 | 13.1 | 1 | 1.2 | 2 | 2.4 |
| Kotmomin | 83 | 5 | 6.0 | 18 | 21.6 | 21 | 25.2 | 17 | 20.4 | 16 | 19.2 | 6 | 7.2 |
| Whole district | 743 | 147 | 19.8 | 169 | 22.8 | 152 | 20.5 | 104 | 14.0 | 67 | 9.0 | 104 | 14 |

Sodicity hazards on the basis of soil pH as described by Ghafoor *et al*, 2004 c.

| Sodicity hazards | No hazards | Non to slightly | Slightly to moderate | Moderate to high | Very high | Extremely high |
|---|---|---|---|---|---|---|

**Table 6. Tehsil-wise number of the most suitable points for citrus production based on EC (≤ 2 dS/m) and pH (≤ 8.2) of soil upto 30 cm and 120 cm depths.**

| Tehsils | Total points | Depth (0-30 cm) | | Total points | Depth (0-120 cm) | |
|---|---|---|---|---|---|---|
| | | No. | Percent | | No. | Percent |
| Sargodha | 40 | 30 | 75 | 37 | 18 | 48.65 |
| Sahiwal | 20 | 5 | 25 | 19 | 2 | 10.53 |
| Silanwali | 21 | 11 | 52.38 | 20 | 6 | 30.0 |
| Shahpur | 31 | 10 | 32.26 | 21 | 4 | 19.05 |
| Bhalwal | 36 | 21 | 58.3 | 7 | 2 | 28.57 |
| Kotmomin | 15 | 7 | 46.67 | 14 | 2 | 14.29 |
| Whole district | 163 | 84 | 51.15 | 118 | 34 | 25.18 |

## CONCLUSION/RECOMMENDATIONS

The study concludes that only 51.15 and 25.18 percent of total points sampled were found quite fit for citrus production upto 30 cm and 120 cm soil depth, respectively. Other soils need some management practices to achieve ideal soil pH (≤ 8.2) and EC level (≤ 2 dS/m) for the establishment of healthy and prolific citrus orchards. It is recommended that before planting the trees, it is desirable to determine the suitability of soil for citrus orchards and if necessary appropriate reclamation measures should be taken. It is also advised that the soil pH of every citrus orchard should be assessed once a year.

## REFERENCES

1. Anon. 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA. Handbook 60, Washington, DC., USA. *In:* STM, Govt. of Punjab, Department of Agriculture.
2. Chaudhry, N.A. 2003. Citrus in Sargodha; Pakistan Horticulture. Pakistan Horticulture Foundation. 2:51-58.
3. Ghafoor, A., M. Qadir and G. Murtaza. 2004a. Sources of salts, genesis and classification of salt affected soils. *In:* Salt Affected Soils. Principles of Management. Univ. Agric, Faisalabad. p.39-42.
4. Ghafoor, A., M. Qadir and G. Murtaza. 2004b. Salt tolerance of crops in salt affected soils: *In:* Salt Affected Soils. Principles of Management. Univ. Agric., Faisalabad. p.110-123.
5. Ghafoor, A., M. Qadir and G. Murtaza. 2004c. Principles of reclamation and management of salt affected soils: *In:* Salt Affected Soils. Principles of Management. Univ. Agric. Faisalabad. p.124.

6. Ibrahim, M., N. Ahmed, S.A. Anwar and S. Javaid. 2004. Citrus management on calcareous soils in Pakistan. Proc. Symp. Plant Nutrition Management for Horticultural Crops under Water Stress Condition. Oct. 5-6, 2004. Quetta. p.79-87.
7. Muhammad, S. 2005. Soil sodicity and water logging. *In:* Soil Science. National Book Foundation, Islamabad. p. 471-492.
8. Quirk, J.P. 2001. The significance of threshold and turbity concentrations in relation to sodicity and microstructure. Aust. J. Soil Sci. 39: 1185-1217.
9. Rajper, I., D. Wright and N.B. Sial. 2003. Effect of soil salinity and sodicity on the growth and yield of durum wheat genotypes. Pak. J. Agric., Agri. Engineering and Vet. Sci: 19(2). 1-7.
10. Rajput, C.B.S. and R. S. Haribau.1999. The health of citrus plants, *In:* Citriculture. Kalyani Publishers, New Delhi (India). p.73-78 and 255.
11. Rajput, C. B. S. and R. S. Haribau. 1999. Special problem in citriculture. *In:* Citriculture. Kalyani Publishers, New Delhi. p. 246-266.
12. Raja, M. E. 2004. Climate and soil for citriculture. *In:* Advances in Citriculture. Jagmander Book Agency, Delhi. p. 68-98.
13. Sabir, M. and A. Ghafoor.2007. Soil management for food security. Pakistan Agric. 1 (4): 1-20.
14. Siddiq, S., M. A. Avais and N.A. Chaudhry. 2007. Soil constraints limiting citrus production and their management. Proc. National Conf. on Citrus Fruit, NARC, Islamabad. USDA Horticultural Foundation of Pakistan, Feb. 1-3, 2007. p.34-39.
15. Singh, S., V.J. Shivankar, M. S.Ladanya., A.D. Huchche, P.S. Shirgure, R.A. Maathi, A.K. Das and V. Vingori. 2002. Citrus-1001 Question Answers. Kalyani Publishers, Ludhiana, India. p. 64-91.
16. Syvertsen, J. P., B. Boman and D. P. H. Tucker. 1992. Salinity in Florida citrus production. Proc. 1st Int. Seminar on Citriculture in Pakistan. Dec. 2-5. 1992.I.A. Khan (ed.), Univ. Agric., Faisalabad. p. 269-274.
17. Updhayay, R. M. and N.L. Sharma. 2002. Determination of soil pH. Manual of Soil, Plant, Water and Fertilizers Analysis. Kalyani Publishers, New Delhi, India. p.66.

**Table 5. Soil pH of citrus growing areas in Sargodha district and levels of sodicity hazards on citrus plants.**

| Tehsils | Total. No. of samples | <8.0 | | 8.0-8.2 | | 8.3-8.4 | | 8.5.8.6 | | 8.6-8.8 | | >8.8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % | No. of samples | % |
| Sargodha | 211 | 25 | 11.8 | 123 | 58.3 | 33 | 15.6 | 13 | 6.2 | 8 | 3.8 | 9 | 4.3 |
| Sahiwal | 112 | 1 | 0.9 | 15 | 13.4 | 25 | 22.3 | 19 | 17.0 | 13 | 11.6 | 39 | 34.8 |
| Silanwalli | 114 | 16 | 14.0 | 25 | 21.9 | 16 | 14.0 | 21 | 18.4 | 19 | 16.7 | 17 | 14.9 |
| Shahpur | 139 | 9 | 6.5 | 29 | 20.9 | 37 | 26.6 | 23 | 16.6 | 10 | 7.2 | 31 | 22.3 |
| Bhalwal | 84 | 21 | 25.0 | 29 | 34.5 | 20 | 23.8 | 11 | 13.1 | 1 | 1.2 | 2 | 2.4 |
| Kotmomin | 83 | 5 | 6.0 | 18 | 21.6 | 21 | 25.2 | 17 | 20.4 | 16 | 19.2 | 6 | 7.2 |
| Whole district | 743 | 147 | 19.8 | 169 | 22.8 | 152 | 20.5 | 104 | 14.0 | 67 | 9.0 | 104 | 14 |

**Sodicity hazards on the basis of soil pH as described by Ghafoor *et al*, 2004 c.**

| Sodicity hazards | No hazards | Non to slightly | Slightly to moderate | Moderate to high | Very high | Extremely high |
|---|---|---|---|---|---|---|