# Physico-chemical Characteristics of Sodic Soils of the Punjab and Haryana and Their Amelioration by the Use of Gypsum

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More than one million hectares of land out of a total cultivated area of about 8 million hectares is affected by salinity and alkalinity in the Punjab and Haryana States of India. Soils have developed from alluvium deposited by the rivers. The climate of this region, where salt affected soils are common, is arid to semi-arid with rainfall varying from 30 cm to 120 cm, 80 per cent of which is received during the three months from July to September. The minimum and maximum mean-temperature varies from 4.7 °C in January to 42.0 °C in June respectively. KANWAR and BHUMBLA (1958), KANWAR and SEIGAL [4], MAHR [5] and POONIA [7] presented data regarding the characteristics of salt affected soils of different districts of this area. Results of experiments on the reclamation of sodic soils of the Kamma series which do not have the problem of a high water table have been presented by KANWAR and BHUMBLA (1958, 1959), SINGH *et al.* [11]. This paper is being presented with the objective of giving information on the nature of the sodic soils with a high water table, and the effect of the application of gypsum to such soils.

## Material and methods

Profiles were exposed in the typical salt affected areas a few weeks before the onset of the rains. Soil samples from different horizons were taken and analysed according to methods given in USDA Handbook No. 60. Cation exchange capacity was determined using sodium acetate for saturating the exchange complex and replacing adsorbed sodium with ammonium acetate. Hydraulic conductivity was determined in disturbed soil samples. Exchangeable calcium and magnesium were estimated using sodium chloride as an extractant.

Field experiments were conducted on a highly saline and sodic soil at Nilokheri in the Karnal district. The area has a high water table fluctuating between 0 to 150 cm from the rainy to summer season and poor drainage both in the surface and sub-surface layers. The analyses of soil samples of a profile representative of the area are presented in Table 1. *Dhaincha (Sesbania cannabina)*, paddy, sudan-grass, wheat, barley, sugarbeet and berseem were grown with and without gypsum. Gypsum was applied at the rate of 22 tons per hectare (which was equivalent to 50 per cent of the gypsum requirement) in 1958 and the residual effect was studied on subsequent crops. All

*Table 1*

**Analysis of soil samples from a representative profile at Nilokheri**

| Depth cm | pH | E.Cex $10^3$ | C.E.C. me/100 g | ESP | Hydraulic conductivity, cm/hr | Gypsum requirement, me/100 g |
|---|---|---|---|---|---|---|
| 0— 15 | 9.8 | 13.30 | 21.4 | 88 | 0.02 | 23 |
| 15— 45 | 9.9 | 7.30 | 20.9 | 93 | 0.03 | 23 |
| 45— 83 | 9.3 | 3.11 | 13.2 | 79 | — | 11 |
| 83—105 | 9.2 | 0.84 | 13.4 | 80 | — | 11 |
| 105—165 | 8.9 | 1.57 | 11.2 | — | — | |

plots received a basal dose of 10 tons of farmyard manure, 55 kg N/ha as ammonium sulphate, and 28 kg $P_2O_5$ and $K_2O$ as single superphosphate and muriate of potash respectively before sowing summer crops. The following doses of fertilizers were applied to other crops (kg/ha):

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Wheat | 45 | 28 | — |
| Barley | 45 | 28 | — |
| Berseem | 28 | 56 | — |
| Sugarbeet | 56 | 56 | 56 |

## Results and discussion

The data regarding some physico-chemical characteristics of the sodic soils of the Punjab and Haryana are presented in Table 2. The soils are highly

*Table 2/a*

**Physico-chemical characteristics of soil samples from saline and sodic profiles of the Punjab and Haryana**

| Name of village and district | Depth cm | pH | Clay % | $CaCO_3$ % | | C.E.C. me/100 g | ESP | G.R. me/100 g | Hydraulic conductivity cm/hr. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $>2\ \mu$ | $<2\ \mu$ | | | | |
| Isra | 0— 14 | 10.2 | 14.5 | 0.76 | 3.30 | 5.92 | 100 | 13.6 | 0.061 |
| Sangrur | 14— 33 | 10.4 | 21.0 | 2.25 | 6.50 | 7.82 | 100 | 9.2 | 0.029 |
| | 33— 48 | 10.0 | 24.8 | 12.58 | 10.50 | 8.00 | — | 8.4 | 0.008 |
| | 48— 63 | 10.0 | 23.3 | 12.42 | 18.00 | 7.24 | 100 | 7.6 | 0.007 |
| | 63—150 | 9.9 | 15.5 | 29.73 | 35.00 | 5.54 | 23 | 4.0 | 0.054 |
| Pogthala | 0— 12 | 9.9 | 12.8 | Nil | Traces | 12.6 | 67 | 20.0 | 0.120 |
| Rohtak | 12— 38 | 10.4 | 17.4 | Nil | Traces | 14.3 | 63 | 7.0 | 0.060 |
| | 38— 67 | 10.3 | 20.8 | Nil | Traces | 15.2 | 70 | 9.0 | 0.060 |
| | 67— 90 | 10.0 | 21.0 | 2.30 | 1.60 | 17.4 | 74 | 9.0 | 0.049 |
| | 90—127 | 9.9 | 16.4 | 2.30 | 1.60 | 11.8 | 68 | 6.0 | 0.310 |
| | 127—180 | 9.5 | 12.0 | 14.80 | 4.20 | 8.2 | 82 | 6.0 | 0.360 |
| Hansi | 0— 30 | 9.7 | 12.8 | — | 3.00 | 5.8 | 77.1 | 4.2 | 0.004 |
| Hissar | 30— 58 | 10.0 | 18.4 | — | 5.25 | 6.2 | 86.1 | 5.6 | 0.003 |
| | 58— 85 | 10.1 | 20.5 | — | 12.80 | 6.6 | 87.7 | 5.6 | 0.002 |
| Qawi | 0— 30 | 9.9 | 20.5 | 4.73 | 2.56 | 13.4 | 79.0 | 9.4 | 0.010 |
| Karnal | 30—150 | 9.8 | 28.0 | 2.35 | 0.84 | 14.7 | 77.0 | 11.3 | — |

deteriorated with a high content of salts and exchangeable sodium. The E. Ce. in nearly all cases is higher near the surface than in deeper horizons. This indicates that in these soils natural leaching is not of much consequence. Because of the presence of a high water table and high evaporation, upward movement of salts is more important than leaching. In all these soils, sodium is the predominant soluble cation. Magnesium is more concentrated than calcium, though it forms a small fraction of the total cations, except in lower horizon samples of the profile at Isra.

Generally sulphate is the predominant anion and in all samples the amount of carbonate and bicarbonate is appreciable. WHITTIG and JANITZKY [12] and JANITZKY and WHITTIG [1] studied the formation of sodium carbonate by the microbial reduction of sulphate and ferric iron. They concluded that high organic matter content, high water-table, heavy inundation and anaerobic conditions result in the transformation of sulphate into bicarbonate. Later OGATA and BOWER [6] studied the effect of native and applied organic matter on sulphate reduction under anaerobic conditions in arid zone soil in the laboratory. They concluded that appreciable reduction of any sulphate does not occur when arid zone soils become anaerobic because of water-logging, unless undecomposed organic matter is present or the soil organic matter content is high, say above 5%.

The salt affected soils in this region do not contain a high amount of organic matter, but still contain appreciable amounts of carbonate and bicarbonate. These data do not support the contention that for the formation of bicarbonate ions in soils the presence of high amounts of organic matter is necessary.

All the soils contain a high amount of soluble boron. Studies by MAIR [5] and POONIA [7] showed a highly significant positive correlation between pH

*Table 2/b*

**Analysis of saturation extract of soil samples from saline and sodic profiles of the Punjab and Haryana**

| Name of village and district | Saturation extract | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | E. Ce × $10^3$ | $Ca^{2+}$ (me/l) | $Mg^{2+}$ (me/l) | $Na^+$ (me/l) | $K^+$ (me/l) | SAR | $CO_3^{2-}$ + $HCO_3$ | $Cl^-$ (me/l) | $SO_4^{2-}$ (me/l) | B ppm |
| Isra | 28.5 | 0.70 | Nil | 315.0 | 2.15 | 532 | 313.2 | 102.8 | 107.0 | 39.0 |
| Sangrur | 11.4 | 0.50 | Nil | 125.0 | 0.85 | 250 | 60.0 | 128.0 | 250.0 | 12.0 |
| | 2.8 | 0.80 | 1.7 | 42.5 | 0.65 | 38 | 17.8 | 15.4 | 57.0 | 4.1 |
| | 2.3 | 5.70 | 24.3 | 105.0 | 4.80 | 27 | 35.6 | 45.6 | 83.8 | 5.5 |
| | 2.0 | 5.30 | 25.7 | 10.5 | 4.75 | 28 | 30.4 | 44.0 | 82.8 | 4.0 |
| Pogthala | 40.4 | Nil | 3.5 | 820.0 | 2.50 | 620 | 339.8 | 127.0 | 375.0 | 26.7 |
| Rohtak | 13.8 | Nil | 1.5 | 168.0 | 2.50 | 193 | 71.0 | 51.0 | 60.0 | 10.5 |
| | 7.2 | Nil | 1.5 | 55.0 | 1.60 | 64 | 29.0 | 11.0 | 21.7 | 10.0 |
| | 8.4 | 1.0 | Nil | 31.0 | 2.10 | 115 | 27.5 | 20.0 | 30.0 | 6.5 |
| | 6.0 | Nil | 1.5 | 60.0 | 2.10 | 69 | 27.1 | 14.0 | 22.6 | 3.8 |
| | 4.8 | Nil | 2.0 | 40.0 | 2.50 | 40 | 24.7 | 13.0 | 23.4 | 3.4 |
| Hansi | 29.1 | 2.60 | 0.6 | 435.0 | 3.10 | | 41.8 | 96.4 | 280.0 | 15.5 |
| Hissar | 15.5 | 1.60 | 0.2 | 173.0 | 0.77 | | 14.0 | 38.4 | 122.0 | 14.0 |
| | 8.7 | 1.60 | 0.3 | 35.0 | 0.22 | | 10.0 | 21.4 | 57.0 | 12.0 |
| Qawi | 11.2 | 0.05 | 0.3 | 97.0 | 2.30 | | 55.0 | 30.0 | 15.0 | — |
| Karnal | 3.8 | 1.20 | 1.1 | 92.0 | 6.60 | | 65.0 | 16.0 | 18.0 | — |

and B content. The probable reason for this appears to be that soluble B, which accumulates at the surface, is not leached out of the profile because of the very low hydraulic conductivity. SAHOTA and BHUMBLA [9], in their studies on the effect of leaching and gypsum on the salt and boron content of soils, reported that leaching of boron is much slower than that of other salts. The hydraulic conductivity is extremely low, so leaching of the salts from these sodic soils without improving the hydraulic conductivity is not likely to be successful. For the same reason, sub-surface drainage is not likely to be effective.

The pH of the soils is near 10.0 with sodium as the predominant exchangeable cation. The exchangeable sodium percentage (ESP) was much higher than 15 and in some cases was higher than 100. SCHULZ *et al.* [10] have reported that soils contain some minerals that are not soluble in water, but are soluble in ammonium acetate. MAIR [5] has reported that in some sodic soils the ESP was even higher than 200.

The sodic soils of the Punjab and Haryana States invariably contain calcium carbonate which usually exists as concretions at some depth. The soils generally do not contain gypsum at any depth. The gypsum requirements of these soils are high, sometimes as high as 50 tons per hectare. It is not always feasible to apply gypsum in quantities indicated by soil tests. For the amelioration and utilization of these soils, the main aim should be to utilize the calcium carbonate present in the soil. A minimum quantity of gypsum may be used to initiate and hasten the process of reclamation. Level topography, monsoonal type of climate, characterised by high intensities of showers of short duration, proceeded and followed by dry season, high water-table, low water intake rate and high exchangeable sodium present serious problems in the drainage of these soils both by surface and sub-surface methods.

Data on the effect of the application of gypsum for different crops are given in Table 3. Though the yields of all crops are below normal, the data clearly bring out the beneficial effect of the application of gypsum. The

*Table 3*

**Yields of various crops as affected by the application of gypsum (kg/ha)**

| Crops | 1958—59 | | 1959—60 | |
|---|---|---|---|---|
| | Without gypsum | With gypsum | Without gypsum | With gypsum |
| Dhaincha (grain) | 0.0 | 0.0 | 325 | 900 |
| Paddy (grains) | 255 | 1060 | 110 | 1 693 |
| Paddy after dhaincha (grain) | 272 | 1595 | 842 | 1 750 |
| Wheat (grain) | 165 | 445 | 413 | 743 |
| Barley (grain) | 205 | 778 | — | — |
| Sugarbeet (Tubor) | 3056 | 5175 | 6725 | 13 494 |
| Sudangrass (fodder) | 62 | 4565 | 0 | 4 857 |
| Berseem (fodder) | 32 | 2137 | 0 | 3 705 |

beneficial effect of gypsum is apparent even in the second year. In these highly deteriorated soils, it is essential to apply an amendment that will increase the availability of calcium in the soil.

KANWAR *et al.* [2] reported that highly sodic soils of the Kamma series, without a high water table, can be reclaimed and economically utilized by growing suitable crops with the application of manures and fertilizers. They placed emphasis on growing crops by the addition of nutrients, particularly nitrogen and phosphorus in which these soils are deficient. Later, studies by SINGH et al. [11] showed that in these soils, calcium from calcium carbonate of the soil can be utilized by following the rotation *Dhaincha (Sesbania cannabina)*, green manured-paddy-barley, with the application of fertilizer. The gypsum treatment produced more noticeable effects on barley than on paddy and applications of up to 50 per cent calcium saturation seemed to be adequate.

The effect of various treatments on soil properties is shown in the data presented in Table 4.

*Table 4*

**Effect of the growth of different crops and gypsum on some soil properties**

| Crop | pH | | | | E.C. × $10^3$ (1:2) | | | |
|---|---|---|---|---|---|---|---|---|
| | With gypsum | | Without gypsum | | With gypsum | | Without gypsum | |
| | spring | fall | spring | fall | spring | fall | spring | fall |
| Dhaincha | 9.2 | 9.7 | 8.6 | 9.8 | 2.06 | 2.42 | 3.01 | 1.20 |
| Rice | 9.5 | 9.5 | 8.3 | 9.2 | 1.70 | 1.22 | 3.18 | 1.77 |
| Dhaincha & rice | 9.3 | 9.4 | 8.9 | 9.2 | 1.33 | 1.05 | 1.33 | 0.67 |
| Wheat | 9.6 | 9.5 | 8.5 | 8.5 | 2.03 | 0.90 | 3.36 | 1.98 |
| Barley | 9.7 | 9.9 | 9.0 | 8.5 | 2.84 | 2.06 | 2.92 | 1.70 |
| Sugarbeet | 9.4 | 9.2 | 8.4 | 7.7 | 1.53 | 1.02 | 3.23 | 2.82 |
| Sudangrass | 9.5 | 10.0 | 8.3 | 9.0 | 2.30 | 1.17 | 1.29 | 0.55 |
| Berseem | 9.5 | 9.7 | 8.8 | 9.2 | 1.87 | 1.58 | 3.00 | 0.91 |

As expected, generally, the pH was appreciably lower in the plots treated with gypsum. The conductivity, which was higher in the gypsum treated plots, even one year after the application, was generally lower in the gypsum treated plots than the untreated plots after the summer crop. This indicates that the application of gypsum in these soils not only reduced the exchangeable sodium, as is evident from a reduction in the pH, but also helped in leaching the salts, at least from the surface 15 cm. As the water table varied between 0 to 120 cm and there was no drainage system the ameliorative effect was not as great as it might have been. Yet, yield data for different crops, as well as the soil analysis, clearly bring out the usefulness of gypsum. The hydrolysis of calcium carbonate which was evident in the soils of the Kamma series does not seem to be of much importance in these highly sodic and saline soils possibly because of the high water table.

## Summary

Profiles of representative saline and sodic areas of the Punjab and Haryana States of India were examined and soil samples from different horizons analysed. The soils contained high amounts of salts with the electric conductivity of saturation extracts of the soils ranging from 4 to 40 mmhos/cm at 25 °C. Sodium formed the predominant soluble cation. Carbonate and

bicarbonate constituted about 50 per cent of the anions. In these soils soluble boron was found to be present in toxic amounts (4.0 – 30.0 ppm in saturation extract). The soils contained very high amounts of exchangeable sodium which in some cases exceeded 100.

Applications of gypsum at the rate of 50 per cent of gypsum requirements resulted in an appreciable increase in the yield of paddy, barley, wheat, sugarbeet, sudangrass, berseem and *Dhaincha (Sesbania cannabina)*. In these soils with shallow water tables the availability of calcium from calcium carbonate does not seem to be of much importance.

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