# EFFECTS OF LEACHING ON SALINITY LEVELS AND OTHER SOIL PROPERTIES OF A CLAY SOIL IN THE LOCKYER VALLEY, QUEENSLAND

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## SUMMARY

Eleven years of leaching following 10 years of irrigation with a saline water reduced soluble salt concentration in the profile to a depth of 120 cm to approximately the levels existing in a non-irrigated soil. This reduction in soluble salts was not accompanied by a similar reduction in pH, sodium adsorption ratio of saturation extract or sodium as a percentage of total exchangeable metallic cations.

Short-term leaching reduced total soluble salt concentration in the profile of a soil salinized as a result of 15 years of irrigation to levels approximating those in the non-irrigated soils in the top 45 cm of profile. pH and sodium adsorption ratio of saturation extract showed only minor changes from those of the 15-year irrigation treatment, while sodium as a percentage of total exchangeable metallic cations increased considerably as a result of the short-term leaching.

## I. INTRODUCTION

The more important of the agricultural soils of the Lockyer Valley in south-eastern Queensland are quaternary alluvium of mixed origin derived from basalts , sandstones, conglomerates and shales. Most are dark grey to dark grey-brown clays with a self-mulching surface horizon. Frequently subsoil horizons are clay loams or sandy clays.

Where underground water is available supplementary irrigation of agricultural crops is practised, often with waters of doubtful quality.

The investigation reported here was conducted on soils from the Mount Whitestone area of the Ma Ma Creek catchment of the Lockyer Valley. Underground waters where available in this area are typically of high salinity. The site was selected because adjacent farmers had adopted different irrigation practices over a period of years.

Farm I contained a large area which had never been irrigated and also an area where irrigation with a saline water had been practised for 10 years before being discontinued. Irrigation had been discontinued 11 years prior to sampling. Farm II had been irrigated for 15 years from a saline bore which was located within 100 m of the bore used when irrigation was practised on farm I. It was felt that these treatments could provide information not only on the increase in soil salinity with continued irrigation but also on the effect of discontinuance of irrigation on soil salinity levels and other soil properties. Following sampling an unusually wet period was experienced (748 mm rainfall over 3 months).

The opportunity was taken to resample the 15-year irrigation area to ascertain the effect of short-term leaching on the removal of soluble salts and associated soil properties.

## II. MATERIALS AND METHODS

Mechanical analysis of typical profiles indicated that the soil under investigation was a clay to a depth of 60 cm overlying clay loam to a depth of 120 cm.

Ten samples from each of the four areas investigated were taken at random and to a depth of 120 cm using a hand auger. Samples were obtained from the following depths: 0–15 cm; 15–30 cm; 30–45 cm; 45–60 cm; 60–75 cm; 75–90 cm; 90–105 cm; 105–120 cm. Samples were air-dried and ground to pass a 2 mm sieve. The treatments referred to later in the text as A, B, C and D are as follows:—

    A—Non-irrigated.

    B—Irrigated 10 years with water of quality similar to C. Irrigation discontinued 11 years prior to sampling.

    C—Irrigated for 15 years at time of sampling.

    D—Resampling of area C after 748 mm of rainfall (slightly in excess of the average annual rainfall of the area) had been received over the 3-month period December 1970 to February 1971 inclusive.

In plotting analytical data shown in Figures 1 to 5 the value for 0–15 cm is plotted at 15 cm; 15–30 cm at 30 cm; 30–45 cm at 45 cm; 45–60 cm at 60 cm; 60–75 cm at 75 cm; 75–90 cm at 90 cm; 90–105 cm at 105 cm; and 105–120 cm at 120 cm.

Salinity levels of the water used for irrigation in these treatments are indicated by the partial analysis figures of Table 1.

### TABLE 1

CHEMICAL COMPOSITION OF IRRIGATION WATER FROM A BORE

| Date | Conductivity (Micromhos/cm 25°C) | Ionic Composition (m–equiv./1) | | | Sodium Adsorption Ratio |
|------|------|------|------|------|------|
| | | $Ca^{++} + Mg^{++}$ | $HCO_3^-$ | $Cl^-$ | |
| October 1968  .. | Not determined | 47·8 | 11·0 | 67·5 | 6·3 |
| April 1971  .. | 5 950 | 43·6 | 10·6 | 53·0 | 4·3 |
| August 1971  .. | 6 135 | 44·2 | 10·4 | 54·6 | 4·4 |

*Chemical methods.*—pH was determined on a 1:2·5 soil:water extract using a Jones Model 0 pH meter. Saturation extracts were obtained by the method set out by Richards (1954). Four hours' standing was employed between saturation and extraction, the extract being obtained by centrifuging at 3 000–4 000 r.p.m.

The following determinations were made on each saturation extract:—

    (1) Electrical conductivity by use of a Philips Conductivity Measuring Bridge Model GM 4249 using immersion cell type PR 9510.

    (2) Calcium and magnesium by atomic absorption (Unicam SP90A Atomic Absorption Spectrophotometer) and sodium by the emission mode of the same machine. (N.B. Only sodium adsorption ratio derived from these results has been used in the text.)

    (3) Chlorides by use of E. E. L. Chloride Meter.

In addition to the above determinations on saturation extracts, exchangeable metallic cations were determined on $1 \cdot 0$ normal ammonium acetate extracts by the method set out by Richards (1954). Calcium and magnesium were determined by atomic absorption and sodium and potassium by flame emission. (N.B. Only sodium expressed as a percentage of total metallic cations has been used in the text.)

## III. RESULTS

For each of the five measured properties 11 analyses of variance were carried out to test differences among observed treatment means. There was one analysis for each depth in the profile and one for the average over all profile depths. Linear and quadratic contrasts among the eight depths were also analysed to investigate treatment effects on the way in which the measured properties vary with depth. Differences in slope or concavity of the treatment graphs indicate the existence of interactions between the treatment and depth factors.

In all analyses there was significant heterogeneity of within-treatment variances. Consequently it was not feasible to use a pooled error mean square for pairwise comparison of treatment means. In such cases, a separate standard error is required for each contrast (Ottestad 1970). Accordingly, the significance of each difference was assessed using the modified version of the Behrens-Fisher test given by Cochran and Cox (1957). The appropriateness of testing all six differences among the four means simultaneously has been demonstrated by computer studies of the least significant difference (L.S.D.) test for small numbers of treatments (Balaam 1963). In the following account of the experimental results, "significant" means that the probability of a Type I error is $0 \cdot 05$ per comparison.

Means of the five measured properties for each treatment taken over all profile depths are shown in Table 2. For pH and S.A.R. there are no significant differences among the B, C and D means, but each of these is significantly larger than the A mean. For conductivity and chlorides all six differences are significant and the value for D lies below that for C. The percent Na+ data shows no significant difference between B and C, but all other differences are significant and the highest mean is that for D.

### TABLE 2

TREATMENT MEANS OVER ALL PROFILE DEPTHS

| Treatment | pH | Conductivity | Chlorides | S.A.R. | % Na+ |
|---|---|---|---|---|---|
| A .. .. .. | 6·39 | 0·338 | 0·92 | 0·996 | 2·14 |
| B .. .. .. | 7·68 | 1·225 | 4·80 | 5·647 | 5·42 |
| C .. .. .. | 7·57 | 4·554 | 39·15 | 7·510 | 6·92 |
| D .. .. .. | 7·63 | 3·302 | 29·05 | 7·238 | 10·91 |

Means for each treatment at each of the eight profile depths are shown in Table 3 and plotted in Figures 1 to 5. Mean values of linear and quadratic contrasts among depths are shown in Table 4.

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**TABLE 3**

TREATMENT MEANS FOR EACH MEASURED VARIABLE AT EACH OF EIGHT DEPTHS IN THE PROFILE

| Variable | Treat-ments | Depth in Profile (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 |
| pH .. .. .. | A | 5·92 | 5·93 | 6·11 | 6·36 | 6·50 | 6·64 | 6·78 | 6·89 |
| | B | 7·06 | 7·06 | 7·23 | 7·59 | 8·14 | 8·21 | 8·16 | 7·97 |
| | C | 7·36 | 7·25 | 7·22 | 7·44 | 7·79 | 7·83 | 7·85 | 7·84 |
| | D | 7·52 | 7·76 | 7·63 | 7·39 | 7·55 | 7·75 | 7·75 | 7·72 |
| Conductivity .. .. | A | 0·505 | 0·444 | 0·332 | 0·262 | 0·258 | 0·253 | 0·269 | 0·383 |
| (millimhos/cm 25°C) | B | 0·915 | 0·924 | 1·072 | 1·156 | 1·128 | 1·318 | 1·412 | 1·874 |
| | C | 4·404 | 4·617 | 4·285 | 3·973 | 3·926 | 4·185 | 5·286 | 5·757 |
| | D | 0·847 | 0·622 | 0·785 | 2·236 | 3·645 | 4·988 | 5·838 | 7·458 |
| Chlorides .. .. | A | 1·62 | 1·28 | 0·81 | 0·52 | 0·80 | 0·59 | 0·70 | 1·06 |
| (m-equiv./litre) | B | 3·48 | 2·58 | 3·05 | 3·62 | 4·91 | 5·84 | 5·14 | 9·81 |
| | C | 39·78 | 43·13 | 38·61 | 33·97 | 30·73 | 34·40 | 44·38 | 48·19 |
| | D | 5·34 | 5·82 | 3·02 | 20·64 | 32·00 | 42·00 | 55·70 | 67·85 |
| S.A.R. .. .. | A | 0·686 | 0·692 | 0·851 | 1·049 | 1·077 | 1·065 | 1·289 | 1·259 |
| | B | 3·929 | 4·683 | 5·620 | 6·327 | 6·333 | 6·780 | 5·994 | 5·506 |
| | C | 6·366 | 5·859 | 7·059 | 7·789 | 8·141 | 9·239 | 8·296 | 7·331 |
| | D | 4·387 | 5·003 | 5·681 | 8·280 | 9·085 | 8·710 | 8·822 | 7·935 |
| % Na .. .. .. | A | 2·01 | 2·04 | 1·89 | 1·90 | 2·12 | 2·31 | 2·53 | 2·32 |
| | B | 4·19 | 4·75 | 5·90 | 5·89 | 6·04 | 5·82 | 5·29 | 5·46 |
| | C | 5·08 | 5·68 | 7·10 | 7·80 | 7·80 | 7·25 | 7·29 | 7·33 |
| | D | 6·10 | 8·37 | 9·52 | 12·32 | 12·52 | 12·26 | 13·02 | 13·20 |

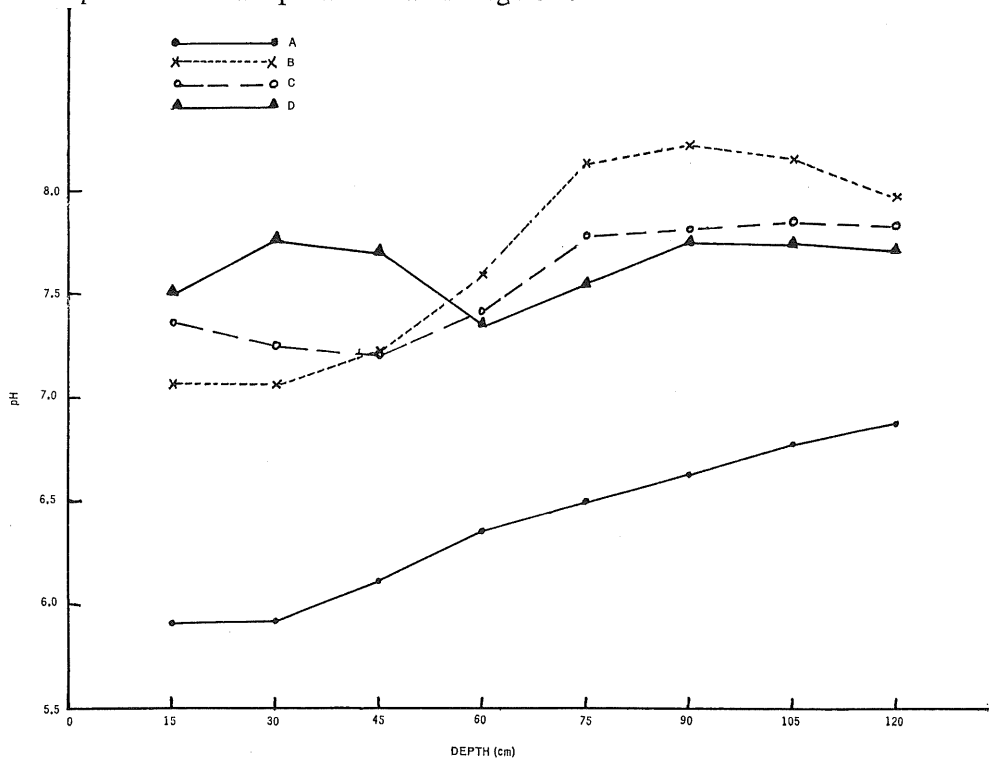*pH.*—Values for pH are shown in Figure 1.



Fig. 1.—Variation of pH with depth of profile for different treatments.

**TABLE 4**

MEAN VALUES OF LINEAR AND QUADRATIC CONTRASTS AMONG DEPTHS

| Contrasts | | | Treat-ments | Variable | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | pH | Conductivity | Chlorides | S.A.R. | % Na |
| Linear | .. | .. .. | A | 12·77 | −1·97 | −7·20 | 7·67 | 6·10 |
| | | | B | 15·36 | 9·86 | 66·77 | 21·08 | 11·50 |
| | | | C | 8·54 | 12·47 | 49·25 | 25·83 | 24·25 |
| | | | D | 1·87 | 86·38 | 815·27 | 53·82 | 81·37 |
| Quadratic .. | | .. .. | A | −0·17 | 2·57 | 9·94 | −0·78 | 2·18 |
| | | | B | −4·54 | 3·27 | 31·43 | −23·78 | −17·22 |
| | | | C | 0·20 | 16·13 | 160·77 | −18·51 | −21·21 |
| | | | D | 1·35 | 17·87 | 175·59 | −29·92 | −33·05 |

At all profile depths the B, C and D treatment means are significantly higher than the A treatment mean. There are significant differences between B and C at the 75 cm and 90 cm depths, and between C and D at the 30 cm and 45 cm depths. Except at 60 cm the differences between B and D are all significant, B being less than D below 60 cm and greater than D above 60 cm. The linear rate of increase of pH with depth is greater for A and B than for C and D. The downward concavity of the graph for B is significantly different from the shape of each of the other three treatments, which do not differ among themselves in this respect, and shows the tendency for B to increase below the 60 cm depth.

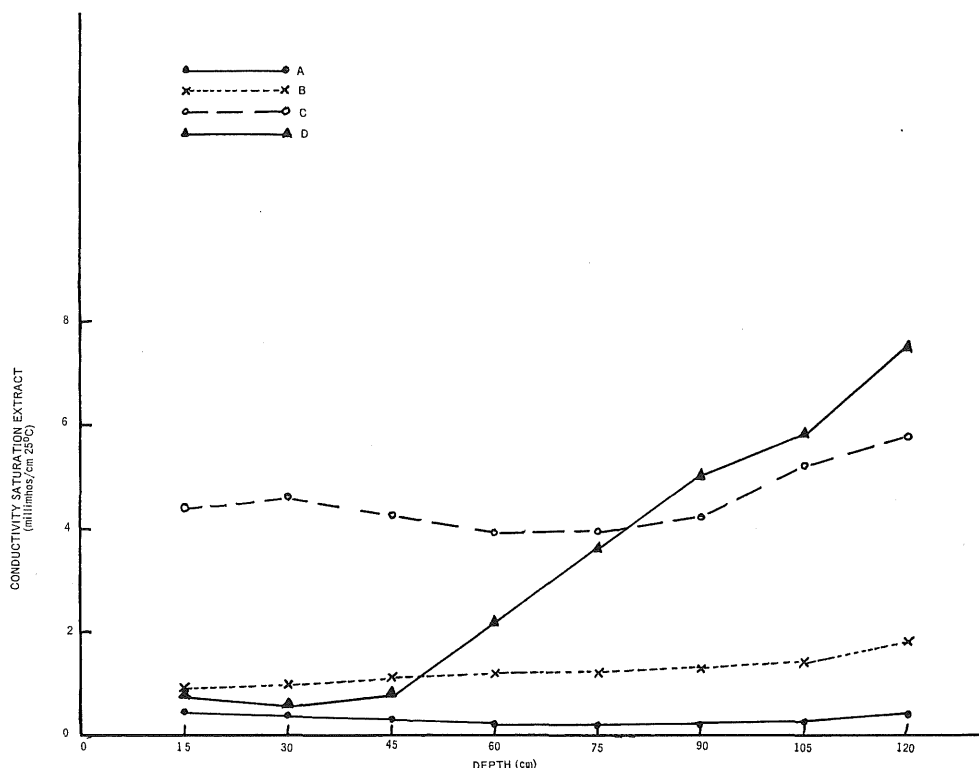*Electrical conductivity.*—Values for electrical conductivity appear in Figure 2.



Fig. 2.—Variation of conductivity with depth for different treatments.

All six treatment differences are significant at the 60 cm depth. At each depth greater than this, all differences except that between C and D are significant. At 15 cm the means for treatments A and D and B and D are not significantly different. The other four differences are significant. At the 30 cm and 45 cm depths all differences are significant except that between B and D. In these three zones, the treatment C mean is conspicuously larger than the other means. The linear rate of increase of conductivity with depth in treatment D is significantly greater than the corresponding values for the other treatments. There are no significant differences in quadratic effects. All graphs are concave upwards.

*Chloride ion concentration of saturation extract.*—Values for chloride ion are shown in Figure 3.
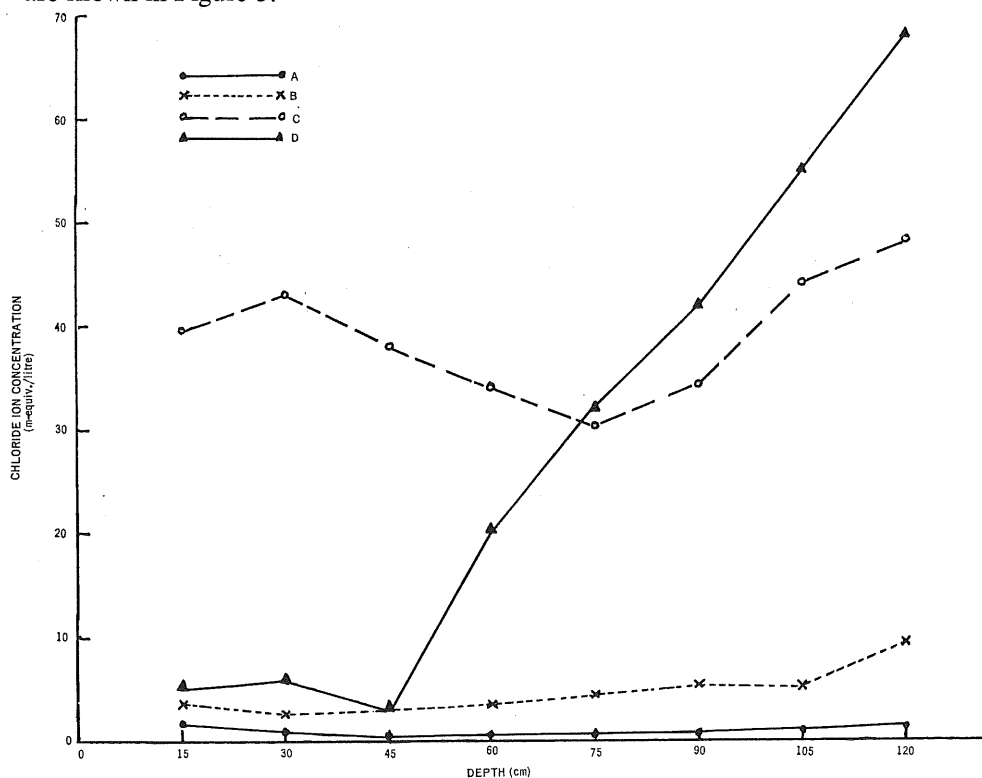


Fig. 3.—Variation in chloride ion concentration with depth for different treatments.

There are no significant differences between the A and B treatments except at 75 cm and 105 cm. The observed difference between A and B at 120 cm is not significant owing to a very large difference between the two within-treatment variances.

The means for treatment C are significantly greater than the means for A, B and D at each zone down to 60 cm. At this zone D becomes significantly greater than A and B. Below 60 cm D increases and is not significantly different from C but these two treatments are each significantly higher than A and B

in these lower zones.   The large linear rate of increase of chloride ion con-
centration with depth for treatment D is significantly greater than the corres-
ponding rates for A, B and C, and these three rates show no significant differences.
All curves are concave upwards but the only significant difference in quadratic
effects is that between D and A.

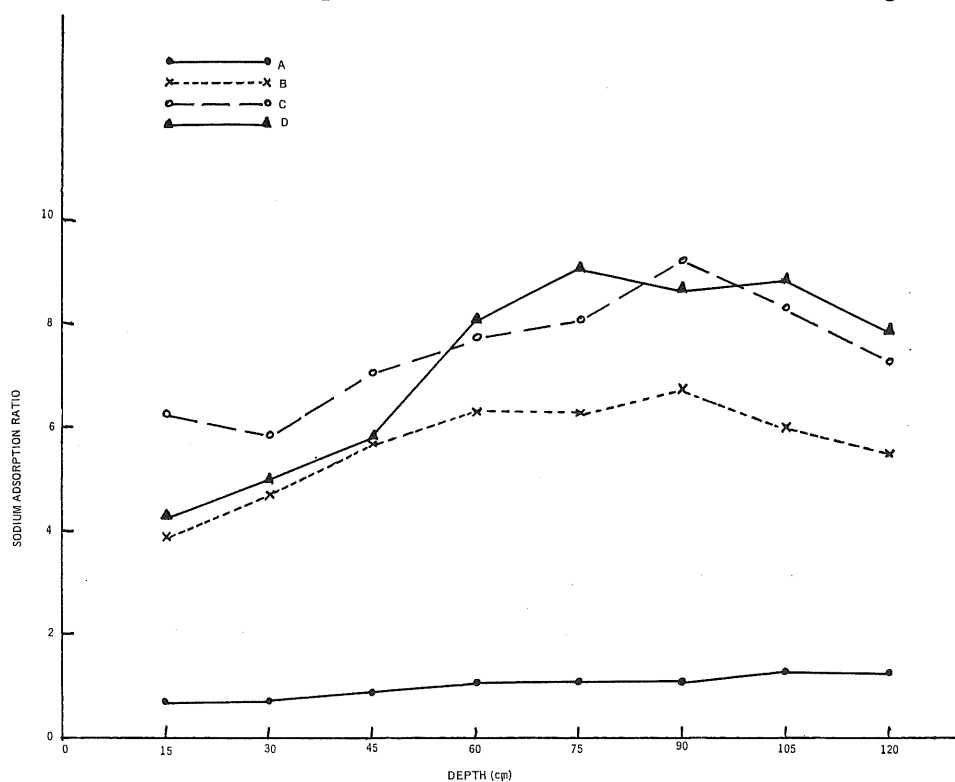    *S.A.R.* (sodium adsorption ratio).—Values of S.A.R. are shown in Figure 4.



Fig. 4.—Variation in sodium adsorption ratio with depth for different treatments.

    At all depths in the profile there are significant differences between A and
each of B, C and D. At 75 cm and 105 cm D significantly exceeds B and at
45 cm C significantly exceeds D. The linear effect for treatment D is significantly
greater than the linear effects for A, B or C.   While all graphs are concave
downwards, the only significant differences in quadratic effects are those between
A and each of B, C and D.

    *Sodium as percentage of exchangeable metallic cations.*—Values for per-
centage sodium appear in figure 5.

    At the 60 cm and 105 cm depths all six treatment differences are significant.
At the 30 cm, 45 cm, 75 cm, 90 cm and 120 cm depths all differences are
significant except that between B and C. At 15 cm the only significant differences
are those between A and C and A and D. The graphs for A, B and C do not
differ significantly in slope but the slope for D is significantly greater than each
of the other three slopes. The B, C and D graphs are concave downwards
with no significant differences. The graph for A is very slightly concave upwards
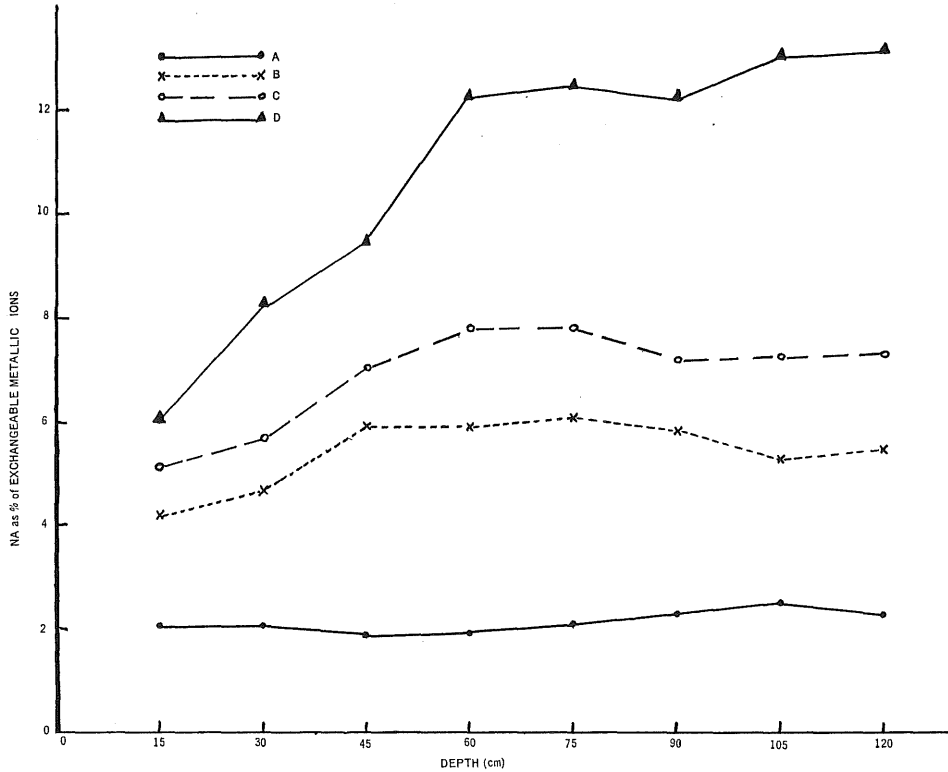and differences from B, C and D are significant.

Fig. 5.—Variation in sodium percentage with depth for different treatments.

## IV. DISCUSSION

Fifteen years of irrigation with a saline water has resulted in salinization of the profile to a depth of 120 cm of a clay over clay loam alluvial in the Mt. Whitestone area of the Ma Ma Creek catchment in the Lockyer Valley. Since the chloride ion was the predominant anion responsible for the salinity of the irrigation water used, it is not surprising that the curves for electrical conductivity of saturation extract and chloride ion concentration of saturation extract are very similar in shape over the full depth of profile examined, and either may be used as an index of salinity levels.

Irrigation results in a significant increase in pH at all profile depths when compared with the non-irrigated treatment. Subsequent leaching by rainfall over a prolonged period (11 years) following cessation of irrigation does little to reduce pH to its original value. On the other hand, prolonged leaching does reduce total soluble salt levels (as reflected by chloride and conductivity of saturation extract measurements) to levels approaching that of the non-irrigated treatment, over the full depth of profile examined.

Irrigation results in a significant increase in both sodium adsorption ratio of saturation extract and in exchangeable sodium expressed as a percentage of total exchangeable metallic cations. Eleven years of leaching following 10 years of irrigation has failed to reduce either of these properties to anywhere near the levels existing in the non-irrigated soil. Short-term leaching (748 mm of rainfall over 3 months) of an area which has been irrigated for 15 years resulted in a marked increase in percentage exchangeable sodium above that existing while the soil was being irrigated. The proportionate increase in sodium percentage was greater at depths exceeding 45 cm, and appears to be correlated with increasing concentrations of soluble salts encountered at these profile depths (Figure 2 and Figure 3). This phenomenon, whereby rapid leaching leads to an increase in exchangeable sodium percentage, probably accounts for the difficulty farmers frequently encounter in preparing a desirable seedbed following periods of heavy rainfall. The use of a precultural irrigation or the addition of gypsum or a combination of these treatments may prove of benefit in overcoming this problem.

## V. ACKNOWLEDGMENTS

## REFERENCES

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