Effect of Gypsum and Stubble retention on Crop productivity in Western Victoria

S.D. Jarwal[1], R.D. Armstrong[1] and P. Rengasamy[2]

1 Agriculture Victoria Horsham, Victorian Institute for Dryland Agriculture, Horsham, Victoria.
[2] Department of Soil Science, University of Adelaide, Glen Osmond. South Australia.

ABSTRACT

The effects of gypsum and stubble retention on soil sodicity and the growth of several crops on three soil types (massive brown, grey and red calcareous) in western Victoria were studied from 1995 to 1997. The trial was a factorial design of two different stubble management regimes (complete retention or burnt) by a once off application of four rates of gypsum (0, 2.5, 5, and 10t/ha). Gypsum reduced dispersion on both the grey and massive brown sodic soils, but had no effect on the calcareous soil, as reflected in improved grain yields. In contrast, stubble retention had no effect. Crop type strongly influenced the effect of gypsum on soil exchangeable sodium percentage (ESP). After two years, gypsum reduced ESP only in the top 10 cm of soil following a wheat-safflower sequence whereas ESP was reduced to a depth of 50 cm following a chickpea-canola rotation. It is suggested that that chickpea and/or canola may have facilitated the movement of gypsum down the profile or induced biological reclamation.

KEY WORDS

sodicity, gypsum, biological reclamation

INTRODUCTION

Alkaline sodic soils comprise half of Victoria’s agricultural land (2) most of which occur in the Wimmera and Mallee regions and are predominantly used for field crop production (3). The dispersive and hardsetting nature of these soils affects crop production via reduced emergence, restricted root growth and poor water and nutrient uptake (5). Gypsum is used on these soils to improve soil structure but the responses are often short-lived (4) and economically unsustainable. While gypsum is an excellent kick-starter, gains in crop production and longer-term improvements in soil structure through amelioration of sodicity are possible if gypsum application and other soil management practices are combined. In this study the effects of different levels of gypsum on three different sodic soils with or without standing stubble were examined on the sodicity and productivity of different crops over three years.

MATERIALS AND METHODS

Field experiments were conducted on three different sodic soils at Nhill (massive brown), Natimuk (grey) and Birchip (red calcareous) in western Victoria. The pH (1:5 in water), exchangeable sodium percentage (ESP), and electrical conductivity (1:5 in water) of the three different soils are given in Table 1. All soils had highly sodic subsoils with different levels of sodicity in the surface 10 cm layer. The massive brown and red calcareous soils were highly saline at depths greater than 50 cm.

Table 1. The pH, ESP, and EC of three sodic soils at various depths.

Depth (cm)	Massive brown			Grey			Red calcareous		
	pH	ESP	EC	pH	ESP	EC	pH	ESP	EC
0-10	7.0	12	0.12	6.4	11	0.18	8.3	8	0.29

10-25	7.9	22	0.39	8.3	18	0.21	9.0	22	0.54
25-50	9.0	34	0.98	9.3	24	0.50	9.1	43	1.20
50-75	9.2	37	1.24	9.4	32	0.86	8.6	43	2.66
75-100	9.1	39	1.62	9.3	35	0.90	8.1	38	4.94

The effects of gypsum (0, 2.5, 5 and 10 t/ha) and stubble management (complete retention and burnt) were examined on the productivity of various crops over three years (1995-1997). Each trial was a split block design, replicated three times, with stubble treatments as the main plots and the four different rates of gypsum as subplots. Gypsum was applied in 1995 only, and stubble treatments were imposed in 1996-1997. Two crops were grown each year at all the sites. The crops included wheat, chickpea, safflower, canola and faba bean. Recommended district practices were followed to grow the crops. Each experimental area was divided into two blocks for each of the two crops assigned each year. Results for plant populations, grain yield (header cuts) and ESP of the massive brown sodic soil are presented here. ESP was determined using the modified Tucker method (6).

RESULTS

Plant population

In 1995 application of gypsum significantly improved the establishment of both wheat and chickpea seedlings on the massive brown and grey soils but there was no effect on the red calcareous soil (data not presented). The effect of gypsum on plant establishment was more pronounced in chickpea than in wheat where the gypsum applied plots had more than four times as many plants as zero-gypsum plots. Similarly, gypsum application (especially at the higher rates) had a beneficial effect on seedling establishment of safflower and canola in 1996 and canola and fababean in 1997 on the brown and grey sodic soils but not on crops grown on the red calcareous soil.

Grain yield

Massive brown soil: Gypsum significantly increased the grain yield of both wheat and chickpea in 1995 on the brown soil (Fig.1). Differences between various gypsum treatments were, however, not significant. On brown soil wheat produced about 75 per cent more grain (1 t/ha) than no gypsum plots while chickpea yield was more than doubled with 2.5 t/ha gypsum. In 1996 canola yield increased significantly from 0 to 2.5 and 2.5 to 5 t/ha. There was a significant increase in safflower yield with 5 t/ha gypsum. In 1997 faba bean yield was significantly improved by gypsum applied in 1995. The differences between the three gypsum levels were not significant. On average the yield of gypsum plots was 60 per cent more than no-gypsum plots. In the case of canola the grain yield increased with increasing amount of gypsum. The significant increase was only achieved with the 5 and 10 t/ha rates of gypsum.

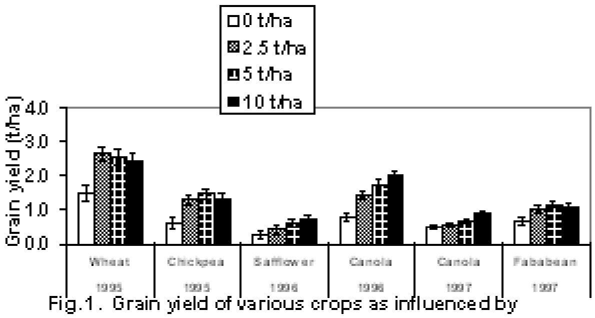

Fig.1. Grain yield of various crops as influenced by gypsum (applied in 1995) on massive brown sodic soil. I - *lsd* (0.05)

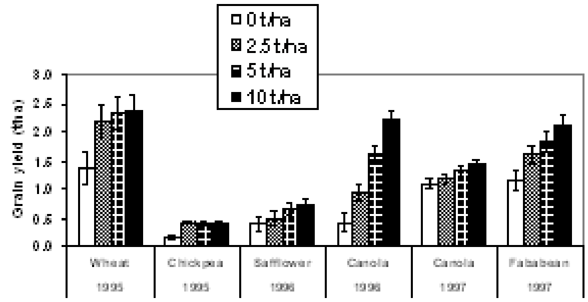

Fig.2. Grain yield of crops as influenced by gypsum (applied in 1995) on grey sodic soil. I - *lsd* (0.05)

Grey soil: Applying 2.5 t/ha of gypsum increased wheat yield by about 60 per cent (Fig. 2). The differences between three gypsum rates were not significant. Increases in chickpea yield due to gypsum application was more pronounced on grey soil. On an average the chickpea yield of gypsum plots was more than two and half times that of no-gypsum plots. In 1996 there was a continuous increase in canola yield with increasing rates of gypsum. Highest yield (2.2 t/ha) was obtained with the 10 t/ha of gypsum (Fig. 4). Significant yield increases in safflower were obtained with 5 and 10 t/ha gypsum rates. In 1997 faba bean yield increased with increasing amounts of gypsum. Plots with 2.5 t/ha gypsum yielded about 40 per cent more than the control. Maximum yield (2.1 t/ha) was obtained with 10 t/ha gypsum which was significantly higher than 0 and 2.5 t/ha gypsum but similar to the yield from the 5 t/ha treated plots.

Red calcareous soil: The increase in wheat yield was not significant in 1995 (Fig. 3), and for chickpea there was a negative effect of gypsum application, rather there was an indication towards the contrary. Though the trend showed reduction in yield with increasing gypsum application the significant reduction was occurred by gypsum applied at the rate of 10 t/ha only. There were no significant responses to gypsum in 1996 and 1997. Overall yield of canola in 1996 was 1.0 t/ha while that of chickpea was very low (0.4 t/ha) due to severe frost damage during grain filling. In 1997 canola emergence was not satisfactory due to continuously dry conditions so the crop was subsequently sprayed out and no yield figures were obtained.

Exchangeable sodium percentage (ESP)

ESP was determined in soil samples collected after two years of cropping from the brown sodic soil. In wheat-safflower plots, gypsum (5 and 10 t/ha) reduced the ESP only in the top 10 cm (Table 2). In chickpea - canola plots, however, a significant reduction in the ESP was achieved with 2.5 t/ha gypsum, with further significant reduction at 10 t/ha gypsum. Furthermore, adding gypsum significantly reduced the ESP to a depth of 50 cm with increasing amounts of gypsum. For example, the ESP of the 10-25 cm soil layer was reduced from about 24 to 15.9 in chickpea - canola plots while in wheat - safflower plots it was reduced from 23.5 to 21 with 10 t/ha gypsum. There was a significant reduction in the ESP of the 25-50 cm soil layer with 10 t/ha gypsum as compared to other treatments. There was a significant reduction in the ESP of the 25-50 cm soil layer with 10 t/ha gypsum as compared to other treatments but the ESP level was still very high at about 30.

Stubble effects

Although trafficability was improved in 1996 and 1997, stubble retention had no significant beneficial effects on crop performance or soil sodicity at any of the sites.

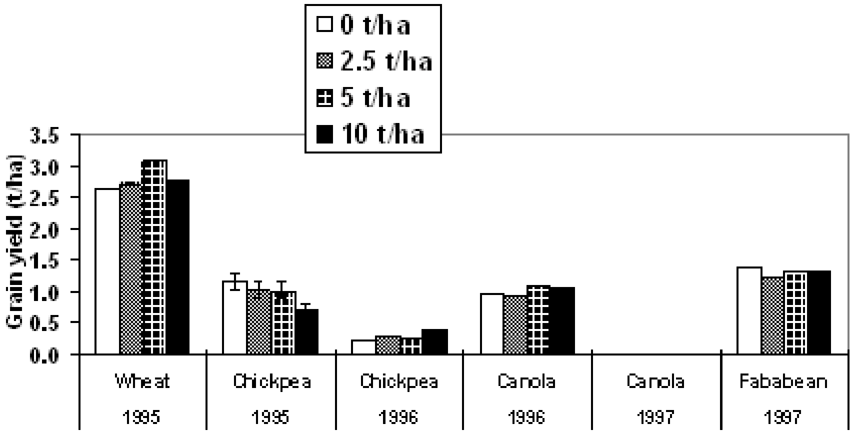

Figure 3: Grain yield of crops as influenced by gypsum (applied in 1995) on red calcareous sodic soil.
I - *lsd* (0.05)

Table 2.

Effect of gypsum (applied in 1995) and crop sequence on ESP of massive brown sodic soil

Crop Sequence	Depth, cm	Gypsum rates, t/ha 0	2.5	5	10	LSD*
Wheat –safflower	0-10	13.6	12.5	9.2	6.4	1.7
Safflower	10-25	23.5	22.4	20.6	21.0	4.0 ns
	25-50	33.8	35.8	33.8	34.4	3.0 ns
	50-75	38.5	37.7	39.9	39.5	2.2 ns
	75-100	38.1	39.6	40.2	39.4	2.4 ns
Chickpea –canola	0-10	13.2	7.3	6.8	4.7	2.7
Canola	10-25	24.3	18.4	17.6	15.9	3.7

25-50	33.6	31.1	31.0	30.0	2.9
50-75	37.4	36.3	38.3	38.6	3.4 ns
75-100	37.5	38	37.7	38.4	3.1 ns

Least significant difference at 5 % level of significance. ns - not significant

DISCUSSION

Gypsum reduced soil dispersion on both the massive brown and grey sodic soils, resulting in improved crop establishment. This translated to increased grain yield, but to a smaller extent (Figures 1 and 2). In 1995 significant crop responses were obtained with gypsum applied at 2.5 t/ha but increasing the amount did not alter the responses significantly. This was probably because the electrolyte concentration required to prevent dispersion was achieved at 2.5 t/ha itself (5) and further addition of gypsum had no effect on reducing soil dispersion. In 1996, on the other hand, positive yield response was obtained with 5 t/ha as compared to 2.5 t/ha on massive brown soil even though there was no significant difference in plant population between the two gypsum treatments. This yield response appeared to be due to improved soil conditions as indicated by reduced sodicity (Table 2) as well as soil strength (data not presented here).

The absence of a positive response to gypsum on the red calcareous sodic soil was explained in terms of its texture and salinity. This soil was in a low rainfall area and coarser than brown and grey sodic soils. As a result it was subject to only infrequent waterlogging. High amounts of soluble salts in this soil also minimised dispersion (electrolyte effect) and helped maintain good structure (Table 1).

Stubble treatment had no effect on crop establishment or grain yield. This may reflect the relatively short time frame the two stubble treatments (2 crops) had to produce only very small changes in soil organic carbon concentrations. However there was a noticeable improvement in trafficability and under commercial conditions this would have allowed farmers to get onto paddocks earlier and create the potential for higher grain yields. This suggests that stubble retention may have decreased ESP in the following years.

Crop type significantly influenced the effect of gypsum on sodicity. In the chickpea – canola sequence, 2.5 t/ha of gypsum had an equivalent effect to that of the 10 t/ha treatment applied to the wheat – safflower sequence on ESP levels (Table 2). This suggests that the tap root system of chickpea and canola may facilitate the movement of water and dissolved gypsum down the profile. Furthermore, the legumes are also capable of reducing rhizosphere pH resulting in the dissolution of $CaCO_3$ and subsequent release of calcium that in turn replaces sodium on the exchange sites. This process of biological reclamation using selected crops with or without gypsum has been successfully demonstrated in India on highly alkaline sodic soils (1).

CONCLUSIONS

The ability of gypsum to reduce dispersion varied with soil type. In contrast, stubble retention had no effect. The effect of gypsum on soil ESP was strongly influenced by crop type. The underlying mechanism responsible for this is unknown. Further investigation into the mechanism responsible for this is warranted as this has important practical implications for increasing the effectiveness of gypsum application in improving soil structure and crop productivity on the highly sodic soils of western Victoria.

ACKNOWLEDGMENTS

This study was co-funded by the Grains Research and Development Corporation. Thanks to Craig Hobbs, Natalie Lewis and Craig Eagle for excellent technical assistance.

REFERENCES

1. Batra, L., Kumar, A., Manna, M.C. and Chhabra, R. 1997. *Exp. Agric.* **33**, 389-397.

2. Ford, G.W., Martin, J., Rengasamy, P., Boucher, S. and Ellington, A. 1993. *Aust. J. Soil Res.* **31,** 869-909.

3. Gardner, W.K., Carter, J., Flood, R., Young, T., Drum, M. and Jasper, M. 1992. *Proc. 6th Australian Agronomy Conference* Armidale, pp 146-149.

4. Jaywardane, N.S. and Chan, K.Y. 1994. *Aust. J. Soil Res.* **32,** 13-44.

5. Rengasamy, P. and Olsson, K.A. 1991. *Aus. J. Soil Res.* **29,** 935-952.

6. Tucker, B.M. (1974). Laboratory procedures for cation exchange measurement on soils. Technical Paper No. 23. (CSIRO Division of Soils: Australia).