Soil Absorption of and Plant Response to Applied Calcium

R.E. Karamanos and N.A. Flore

Western Co-operative Fertilizers Limited,
P.O. Box 2500, Calgary, Alberta T2P 2N1

Calcium (Ca) is an element that is considered a macronutrient as higher plants generally contain 5-30 mg Ca/g dry matter (Mengel and Kirkby 1979). Deficiencies of Ca as a nutrient are uncommon (Haby et al. 1990). Neutral and alkaline soils normally contain adequate Ca, while acid soils are usually limed to provide a favourable pH for most crops. Only highly weathered, leached soils under humid conditions are normally low in Ca.
It is often difficult to separate the effect of Ca from that of Ca-bearing compounds, such as lime and gypsum. Gypsum often applied as an ameliorant to Na affected soils provides a Ca-related benefit. This benefit can occasionally result from a high pH and bicarbonate-induced Ca deficiency (Rhoades and Miyamoto 1990), however, most of the time is not due to a Ca deficiency, but improvement in soil structure. In western Canada, responses to Ca have been reported in the Peace River Region and East Central Alberta (Figure 1) and are associated with soils of high Na content (Haby et al. 1990).

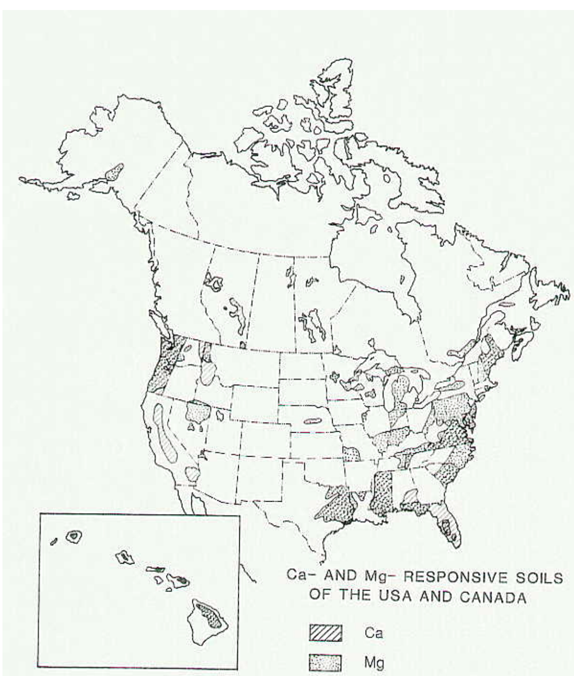

Figure 1. Generalized areas of soils in the USA and Canada on which crops frequently respond to applications of Ca and Mg (Haby et al. 1990).

The Ca fertility of soils is influenced by a number of factors, including total Ca supply, soil pH, cation exchange capacity (CEC), soil mineralogy and percent Ca saturation of soil colloids. Bear et al. (1945) proposed that the ideal base saturation of soil colloids was 65% of Ca, 10% of Mg

and 5% of K. This concept is known as basic cation saturation ratio or simply cation-ratio. Subsequent research demonstrated that soils of much wider ratios behaved similarly (Haby et al. 1990; Kamprath 2000).
The Ca content of a number of soils samples from western Canada is shown in Table 1.

Table 1. A survey of Ca levels of 1,220 western Canadian soils*

Soil type	1N NH_4OAc extractable Ca, mg kg^{-1}
Non-calcareous	3200 ± 1051
Calcareous	6560 ± 3235
All soils	4050 ± 5263

*Courtesy Enviro-Test Laboratories.

The Ca levels of over 1000 plant samples analysed by Enviro-Test Laboratories in the summer of 1997 showed that the Ca level of only 10 samples (Table 2) tested below the critical levels adopted by the laboratory. Admittedly, no work on establishing Ca critical levels has been carried out in western Canada with local varieties, therefore, the criteria that have been derived primarily from work in the United States and Australia may not be applicable. In any event, Ca deficiencies in western Canada are not common.

Table 2. Ca levels of crops submitted to Enviro-Test Laboratories in 1997.

Crop	Tested less than critical level	Total number of samples tested
Cereals	7	518
Oilseeds	3	352
Forages and Grasses	0	91
Potatoes	0	85
Total	10	1025

The objectives of this work were:

- To assess Ca adsorption by soil colloids in a series of soils of varying CEC. This part was carried out in response to claims that existing exchangeable Ca levels in western Canadian soils are not “available”; therefore, there is a need for “soluble” Ca to be applied to soil to provide a ready source of Ca.
- To assess the response of canola to a Ca seed treatment.
- To assess the response of barley, wheat and potatoes to Ca and the impact of Ca on potato disease suppression.

MATERIALS AND METHODS

Calcium Adsorption by Soils

This study was carried out at Enviro-Test Laboratories, Saskatoon. Five soil samples were selected based on their texture, CEC and levels of carbon (Table 3). Total carbon was determined by dry combustion in a CSN analyzer (Nelson and Sommers 1996) and inorganic carbon by distillation and subsequent titration (Tiessen et al.1983). Particle size analysis was determined by the standard Bouyoukos hydrometer method and CEC my extraction with 1N NH4OAc (Sumner and Miller 1996). Organic carbon was calculated as the difference between total and inorganic carbon.

Table 3. Carbon forms, particle size analysis and CEC of soils used in the study.

	Carbon, %			Sand	Silt	Clay	CEC
Soil	Total	Inorganic	Organic		%		me/100g
#1	0.10	0.05	0.05	98	0	2	0.3
#2	1.54	0.02	1.52	72	18	10	10.8
#3	1.95	0.04	1.91	62	24	14	14.2
#4	1.90	0.08	1.82	40	36	24	17.8
#5	2.14	0.06	2.08	26	36	38	25.9

A series of seven saturation pastes were created with each soil as shown in Figure 2, each to be used for determining Ca at time 0 and ½, 1, 2, 4, 6 and 24 hours equilibration. Each treatment (time) was replicated three times.

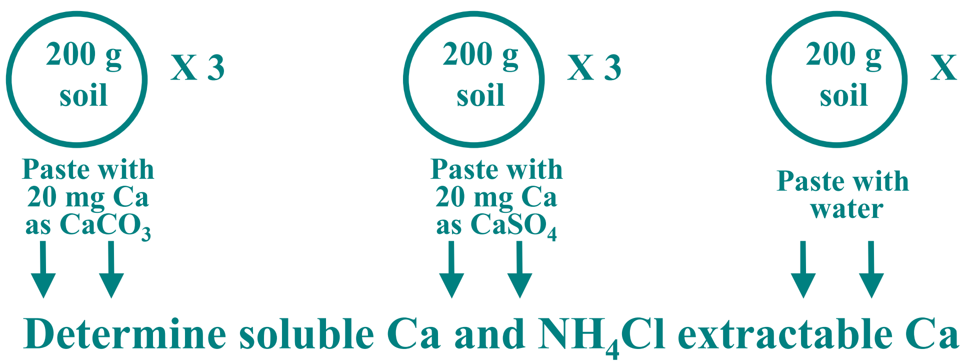

Figure 2. Diagram depicting the procedure used to assess Ca adsorption by soil types.

In addition to soluble and exchangeable (extractable) Ca, the pH of the saturation paste was determined. Ca-saturation was calculated from exchangeable Ca (extractable – soluble) and CEC data for each soil.

Response of Canola to Ca Seed Treatment

A series of six experiments were carried out with Quest canola in Alberta in 1999 using seed treatment Ca5S at a rate of 240 ml/45 kg seed (Table 4).

Table 4. Plot characteristics and experimental parameters for the Ca seed treatment study.

Location	Implement	# of Rows	Space (in.)	Length (ft)	Fertilizer rate, lb/ac N	P_2O_5	K_2O	S	Date of: Seeding	Harvest
Irricana	Airseeder	6	9	25	72	14	50	18	May 6	Sept 22
Irricana	Airseeder	6	9	25	72	14	50	18	June 8	Oct. 1
Wetaskiwin	Double disk drill	4	7	23	81	27	50	18	May 25	Oct. 4
Rimbey	Airseeder	6	9	25	90	27	27	11	May 25	Oct. 12
Lamont	Airseeder	6	9	25	72	0	50	18	May 27	Sept 14
Herronton	Airseeder	6	9	25	72	27	50	18	Apr. 28	Sept. 7

Plant samples were obtained at early flowering from all plots of all experiments, except from the Herronton site. The whole plant samples were analyzed for N, P, K, S, Ca, Mg, Cu, Fe, Mn, Zn and B content.

Response of Wheat and Barley to Seed-placed Ca

Nine experiments with barley and seventeen with wheat were conducted from 1989 to 1994 at a number of locations in Alberta, Saskatchewan and Manitoba (Tables 5 and 6). All plots were seeded with a double disc press drill with 6 rows and 7-inch spacing. The length of the plots was 20 feet. Calcium was seed-placed as $CaCl_2$ at a rate of 15 lb Ca/acre.

Table 5. Experimental parameters for the Ca seed-placement study with barley.

Year	Location	Variety	Fertilizer rate, lb/ac N	P_2O_5	K_2O	S	Date of: Seeding	Harvest
1989	Calgary, AB	Harrington	72	27	27	0	May 5	Aug. 11
	Irricana, AB	Harrington	72	27	27	0	May 9	Aug. 18
	Conrich, AB	Harrington	72	27	27	0	May 10	Aug. 14
1990	Calgary, AB	Heartland	45	27	27	0	May 14	Aug. 18
1991	Crossfield, AB	Harrington	72	27	27	0	May 6	Aug. 31
	Bentley, AB	Stacey	60	27	27	0	May 30	Sept. 4
1992	Camrose, AB	B1602	72	27	27	0	May 16	Aug 26
1993	Red Deer, AB	Harrington	72	27	27	0	May 12	Sept. 7
	Lethbridge, AB	Harrington	107	27	27	0	Apr. 29	Aug. 19

Table 6. Experimental parameters for the Ca seed-placement study with wheat.

			Fertilizer rate, lb/ac				Date of:	
Year	Location	Variety	N	P_2O_5	K_2O	S	Seeding	Harvest
1990	Calgary, AB	Conway	45	27	27	0	May 2	Aug. 23
	Irricana, AB	Conway	72	27	27	0	May 2	Aug. 23
1991	Champion, AB	Conway	54	27	27	0	May 1	Aug. 20
	Champion, AB	Conway	36	27	27	0	May 1	Aug. 20
	Gladstone, MB	Roblin	63	27	27	0	May 18	Aug. 16
	Minnedosa, MB	Roblin	63	27	27	0	May 18	Aug. 18
	Cardale, MB	Roblin	94	27	27	0	May 17	Aug. 17
	Shoal Lake, MB	Roblin	63	27	27	0	May 17	Aug. 15
1992	Gladstone, MB	Katepawa	72	27	27	0	May 25	Sept. 24
	Foxwarren, MB	Katepawa	72	27	27	0	May 27	Sept. 23
	Binscarth, MB	Katepawa	72	27	27	0	May 20	Sept. 22
1993	Neepawa, MB	Roblin	65	27	27	0	May 23	Sept. 30
	Strathclair, MB	Roblin	65	27	27	0	May 22	Sept. 29
	Shoal Lake, MB	Katepawa	40	27	27	0	May 21	Sept. 27
	Churchbridge, SK	Katepawa	65	27	27	0	May 21	Sept. 26
1994	Shoal Lake, MB	Roblin	72	27	27	0	May 22	Sept. 17
	Yorkton, SK	Roblin	72	27	27	0	May 26	Sept. 12

Response of Potatoes to Ca application

Experiments were carried out in 1999 and 2000 at Vauxhall and Taber, Alberta, respectively, to assess among other parameters the effect of Ca on the yield and quality rating of potatoes. These experiments were carried out on farmer fields by selecting plots four rows wide (row spacing 36 inches) with 20 feet lengths. Two hundred lb of Ca/acre were applied in the form of Calcium Sulphate (CalSul) and were incorporated in the soil through the hilling operation. Other treatments included rates of phosphate and a control. The treatments were replicated four times. Petiole samples from each plot were obtained on a biweekly basis and were submitted for complete nutrient analysis, including NO_3-N. Potatoes were harvested at 7.2 feet lengths from each plot. Yield was determined for all four replicates and quality characteristics on only two replicates of samples that were placed in commercial storage for two months.

RESULTS AND DISCUSSION

Calcium Adsorption by Soils

Nemeth et al. (1970) showed that there is a fairly linear relationship between the exchangeable Ca^{2+} and the Ca^{2+} in the soil solution under equilibrium conditions. A close relationship between soluble and exchangeable Ca^{2+} was demonstrated in this study (Figure 3).

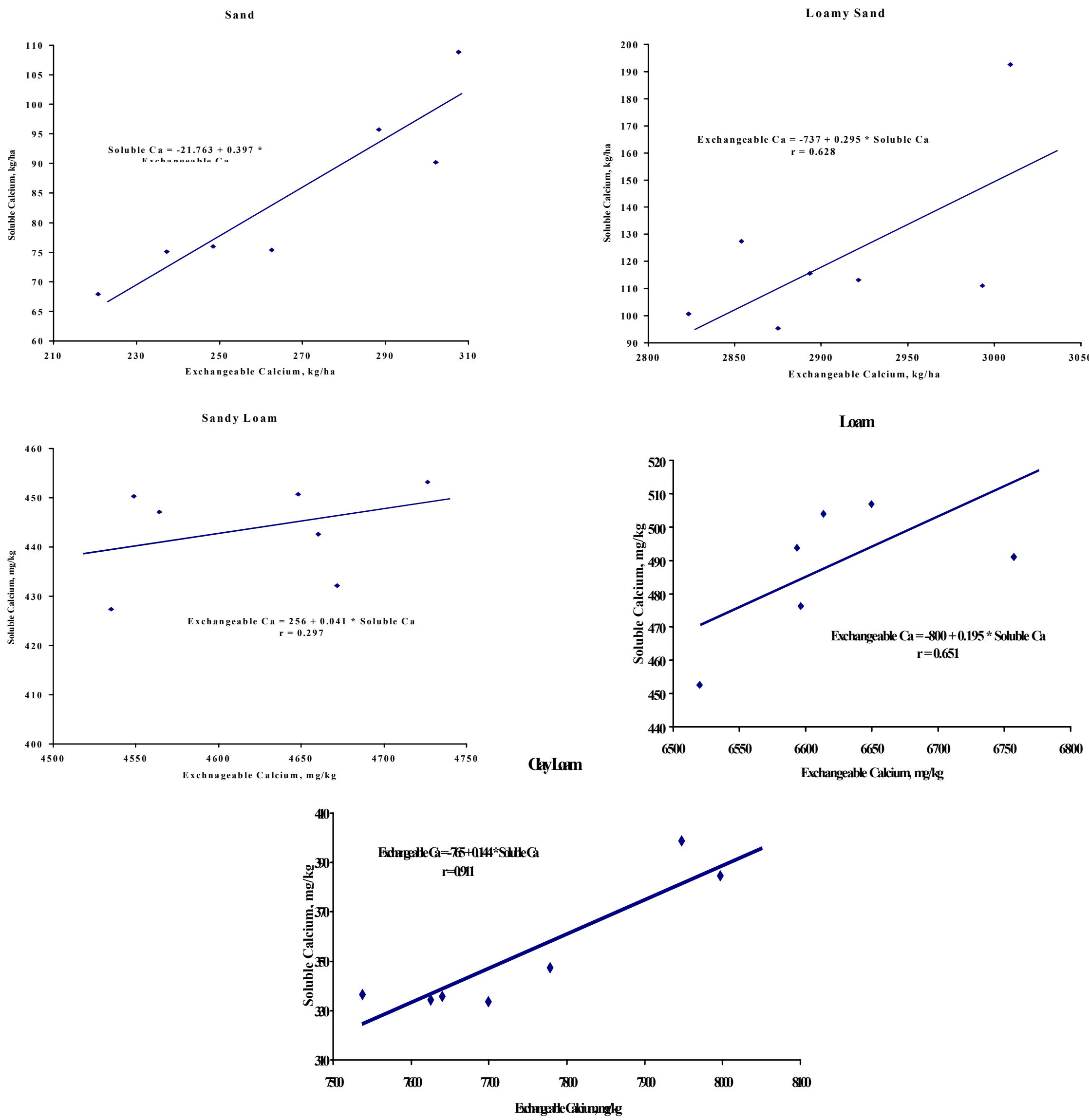

Figure 3. The relationship between soluble and exchangeable Ca^{2+} in the 5 soils studied. Exchangeable Ca^{2+} was 2 to 20 fold of soluble Ca^{2+}concentration. Soluble Ca^{2+} levels even on the sandy soil far exceeded the minimum level of 20 mg/L that was calculated by Barber et al. (1963) as the mass flow supply requirement by alfalfa.

The portion of applied Ca^{2+} remaining in solution after the corresponding equilibration time was calculated by subtracting the concentration of soluble Ca^{2+} of the control from that of either the gypsum or lime treatments and dividing by the amount of applied Ca^{2+} (100 mg/kg soil). The recovery of soluble Ca^{2+} was directly associated with the soil texture and CEC. The loam and clay loam soils adsorbed over 90% of the applied Ca^{2+} as gypsum after 24 hours of equilibration (Figure 4). The sandy loam and loamy sand adsorbed 60-65%, whereas the sandy soil adsorbed only 25%.

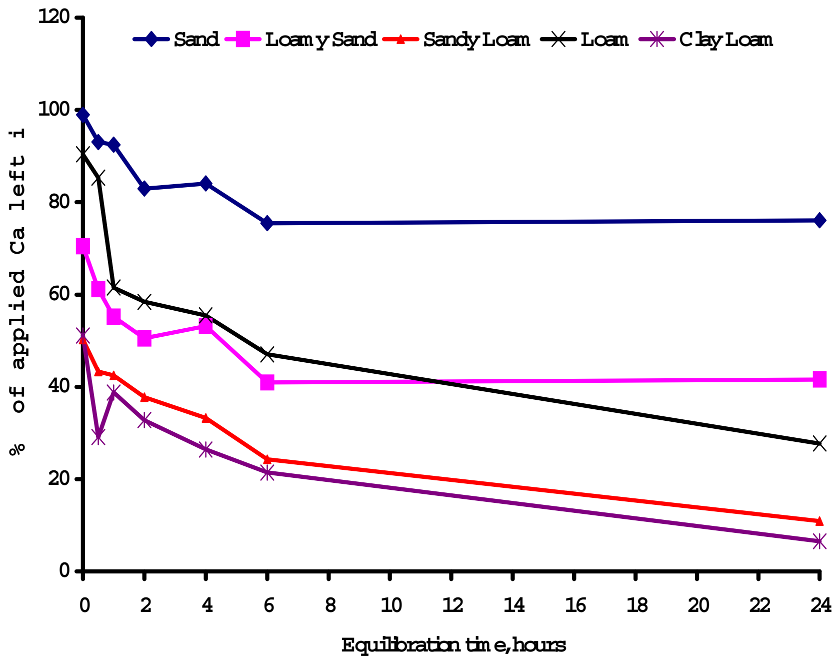

Figure 4. Recovery of applied Ca^{2+} as $Ca(SO_4)_2$ in the saturation extract.

The proportion of applied Ca^{2+} that was left as soluble Ca^{2+} in the saturation extract from the lime treatments was by far less than that from the gypsum treatments (Figure 5). Thus, only approximately 5-15 % of the applied $CaCO_3$-Ca was recovered in the saturation extract of the soils after 24 hours of equilibration.

The results of these experiments demonstrate that there is no advantage to applying a "soluble" form of Ca to the soil at seeding in order to supply the soil with readily available Ca as the majority of applied Ca is quickly adsorbed onto the exchange sites of soil colloids.

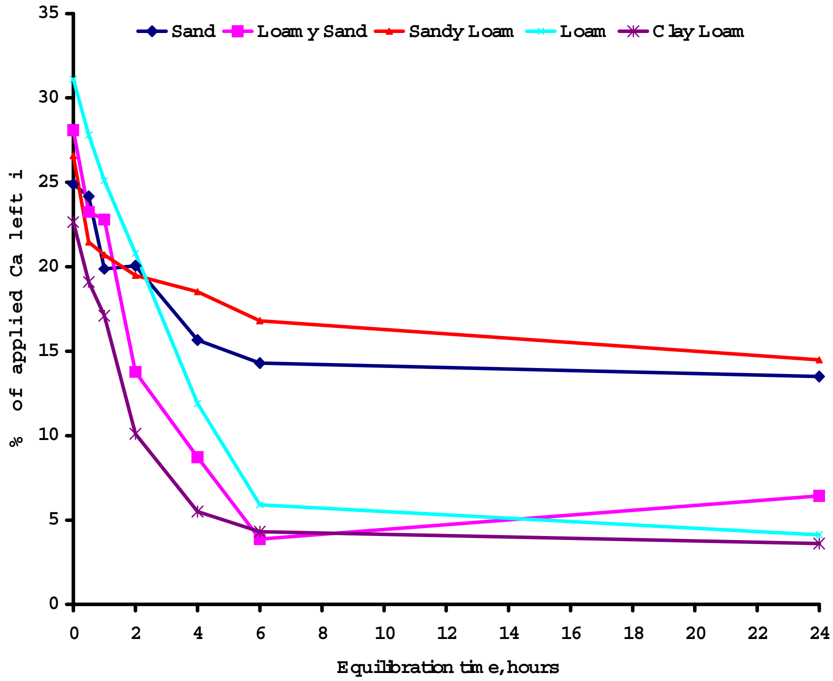

Figure 5. Recovery of applied Ca^{2+} as $CaCO_3$ in the saturation extract.

Response of Canola to Ca Seed Treatment

There was no significant response of Quest canola to the application of Ca5S seed treatment in all six experiments (Figure 6)

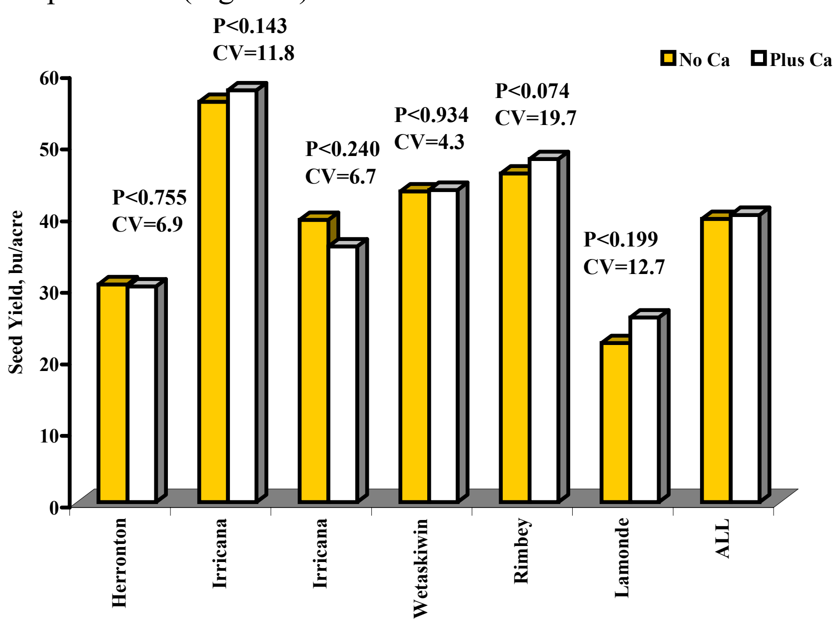

Figure 6. Effect of seed treatment Ca5S on the yield of Quest canola.

The Ca5S treatment had no significant effect on the Ca concentration of canola plant tissue at early flowering (Figure 7).

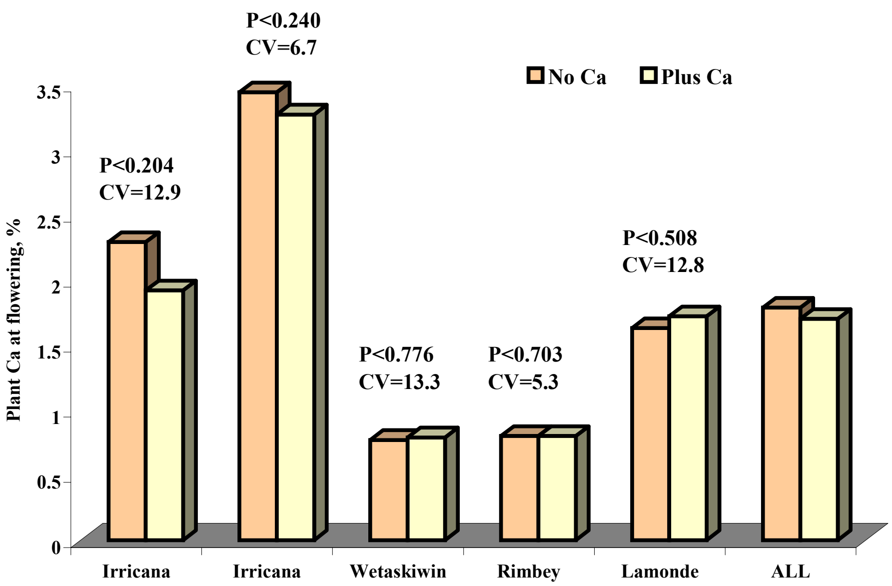

Figure 7. Effect of seed treatment Ca5S on the Ca levels of Quest canola tissue.

Response of Wheat and Barley to Seed-placed Ca

There was no significant effect of seed placing small amounts of Ca as $CaCl_2$ with either barley (Table 7) or wheat (Table 8).

Table 7. The effect of seed-placement of 15 lb Ca/acre as $CaCl_2$ on the yield of barley.

Year	Location	Variety	Control	+Ca	Significance
			____ bu/acre	____	
1989	Calgary, AB	Harrington	91.8	96.3	ns
	Irricana, AB	Harrington	89.6	86.5	ns
	Conrich, AB	Harrington	82.6	84.5	ns
1990	Calgary, AB	Heartland	122.6	127.1	ns
1991	Crossfield, AB	Harrington	108.7	108.4	ns
	Bentley, AB	Stacey	88.1	93.0	ns
1992	Camrose, AB	B1602	60.8	60.6	ns
1993	Red Deer, AB	Harrington	118.5	122.0	ns
	Lethbridge, AB	Harrington	147.9	149.9	ns
	All		101.2	103.1	

Table 8. The effect of seed-placement of 15 lb Ca/acre as $CaCl_2$ on the yield of wheat.

Year	Location	Variety	Control	+Ca	Significance
			bu/acre		
1990	Calgary, AB	Conway	81.5	83.8	ns
	Irricana, AB	Conway	61.8	62.5	ns
1991	Cahmpion, AB	Conway	26.7	26.9	ns
	Cahmpion, AB	Conway	34.6	39.5	ns
	Gladstone, MB	Roblin	41.0	41.0	ns
	Minnedosa, MB	Roblin	56.1	53.5	ns
	Cardale, MB	Roblin	25.9	24.3	ns
	Shoal Lake, MB	Roblin	45.7	44.1	ns
1992	Gladstone, MB	Katepawa	66.3	65.2	ns
	Foxwarren, MB	Katepawa	42.9	44.2	ns
	Binscarth, MB	Katepawa	45.9	48.8	ns
1993	Neepawa, MB	Roblin	46.9	47.3	ns
	Strathchair, MB	Roblin	36.6	36.5	ns
	Shoal Lake, MB	Katepawa	44.4	42.4	ns
	Churchbridge, SK	Katepawa	34.7	37.6	ns
1994	Shoal Lake, MB	Roblin	35.3	35.1	ns
	Yorkton, SK	Roblin	47.8	47.4	ns
	All		45.5	45.9	

Response of Potatoes to Ca application

There was no effect of Ca application at 200 lb Ca/acre as $Ca(SO_4)_2$ in either 1999 or 2000 (Figure 8).

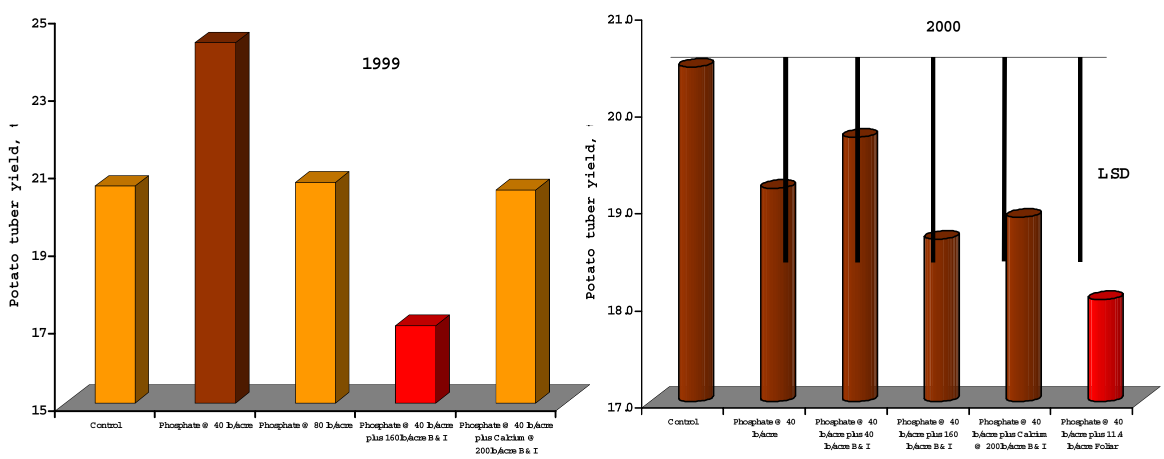

Figure 8. Yield of potatoes at Vauxhall (1999) and Taber (2000) Alberta.
Application of 200 lb of Ca/acre resulted in poorer quality of potatoes (Table 9).

Table 9. Quality assessment of potatoes from the 1999 experiments after storage at a commercial storage for six months (ratings provided by Lamb-Weston).

	Yield	Sp. Gravity	Size 410	Total C.P.	Rot	Stem end	Discolored	Hollow Heart
Control	2	Pass	3	Fail	2	1	2	1
40 lb P_2O_5	1	Pass	1	Pass	2	2	1	1
80 lb P_2O_5	2	Fail	3	Fail	3	1	3	2
200 lb P_2O_5	3	Pass	4	Fail	1	1	2	1
200 lb Ca	2	Fail	2	Fail	4	2	3	2

Conclusions

Western Canadian soils are very well supplied with calcium. Application of low calcium rates (100 mg/kg) has no marked effect on soluble Ca levels in the soil.

Seed treatment of canola with Ca has no impact on either canola yield or Ca levels in the tissue. Seed-placement of low Ca levels had no impact on the yield of wheat and barley. Application of 200 lb Ca/acre as Ca(SO4)2 had no effect on the yield of potatoes and in two experiments in 1999 resulted in lower quality of stored potatoes.

References

Barber, S.A., Walker, J.M. and Vasey, E.H. 1963. Mechanisms for the movement of plant nutrients from the soil and fertilizer to the plant root. J. Agr. Food Chem. 11: 204-207.

Bear, F.E., Prince, A.L. and Malcolm, J.L. 1945. Potassium needs of New Jersey soils. New Jersey Agric. Exp. Stn. Bull. 721.

Haby, V.A., Russelle, M.P. and Skogley, E.O. 1990. Testing soils for potassium, calcium and magnesium. p 181-227. *In* R.L. Westerman (ed.) Soil testing and plant analysis. SSSA Book Series 3. SSSA, Madison, WI.

Kamprath, E.J. Soil fertility and plant nutrition. p. D-1:189. *In* , M.E. Sumner (ed.-in-chief) Handbook of Soil Science. CRC Press, Boca Baton FL.

Mengel, K. and Kirkby, E.A. 1979. Principles of plant nutrition. 2nd Edition, International Potash Institute, Bern, Switzerland.

Nemeth, K., Mengel, K. and Grimme, H. 1970. The concentration of K, Ca, and Mg in the saturation extract in relation to exchangeable K, Ca, and Mg. Soil Sci. 109: 79-195.

Nelson, D.W. and Sommers, L.E. 1996. Total carbon, organic carbon and organic matter. p. 961-1010. *In* D.L. Sparks et al. (ed.) Methods of soil analysis. Part 3. Chemical methods. SSSA Book Series no. 5. SSSA, Madison, WI.

Rhoades, D. and Miyamoto, S. 1990. Testing soils for salinity and sodicity. p 299-336 . *In* R.L. Westerman (ed.) Soil testing and plant analysis. SSSA Book Series 3. SSSA, Madison, WI.

Sumner, M.E. and Miller, W.P. 1996. Cation exchange capacity and exchange coefficients. p. 1201-1230. *In* D.L. Sparks et al. (ed.) Methods of soil analysis. Part 3. Chemical methods. SSSA Book Series no. 5. SSSA, Madison, WI.

Tiessen, H, Roberts, T.L. and Stewart, J.W.B. 1983. Carbonate Analysis in Soils and Minerals by Acid Digestion and Two-Endpoint Titration. Commun. Soil Sci. Plant Anal. 14(2), 161-166.