BORON AND SALINITY SURVEY OF IRRIGATION PROJECTS IN SASKATCHEWAN

W. Nicholaichuk, A.J. Leyshon, Y.W. Jame and C.A. Campbell

INTRODUCTION

Boron is an essential element for plant growth but the limits between deficiency and toxicity are very narrow. Generally, B toxicity becomes a problem in three cases: (1) overfertilization of B-deficient plants with B; (2) in arid soils where B is inherently high; and (3) under irrigation either with B rich waters or where improper irrigation management may result in salt and /or B accumulation in the root zone.

Boron fertilization is not a common practice in Western Canada so problems with the first case have not arisen. With regard to the second and third cases, problems of B toxicity have been overshadowed by the related problem of salinity. As a result, very little attention has been paid to B toxicity.

Recently, concern has been expressed about the quantities of B that might result from the operation of the Coronach Thermal Power Plant ash lagoons and heat exchanger reservoirs. It is feared that if these are discharged into the Poplar River it may lead to undesirable B levels in the irrigation water downstream.

The International Poplar River Water Quality Board and Committees of the International Joint Commission apparently encountered difficulties in trying to establish acceptable concentrations for B and TDS in the Poplar River. They suggested that there was a paucity of data on which to come to a satisfactory conclusion and suggested that little original research on B toxicity had been carried out since Eaton's sand culture work in 1944.

Interest in the B toxicity problem has now extended beyond this specific area to concern over the use of any impounded surface or groundwater where evaporation may tend to increase B concentrations of irrigation water to toxic levels.

A request was made by Mr. Grant Mitchell, former Deputy Minister of Saskatchewan Environment, that Agriculture Canada "collect information on crop production under stress conditions induced by B and TDS in irrigation water" and set up studies at Swift Current to develop some criteria for future application. Consequently, we conducted a survey of irrigation projects to assemble information on B concentration in irrigation waters, soils and crops. This information is required to determine whether a B toxicity problem could eventually arise.

This paper summarizes the results of a survey of 29 surface water, groundwater and municipal effluent irrigation projects in Saskatchewan. The survey was made during the summer of 1982.

METHODOLOGY

The survey included projects operated by PFRA, Saskatchewan Agriculture and by private individuals throughout Saskatchewan (Fig. 1). Legal description of all sites are given in Table 1. Irrigation projects were categorized as surface water, groundwater and effluent dependent on their source of water. At each site, representative samples of plants, water and soils were collected at the beginning and the end of a 3 month period.

Table 1. Legal locations of irrigation projects in Saskatchewan that utilize surface water (S), groundwater (G) and effluent (E)

Gull Lake (E)	NE 1/4 24-19-13-W3	
Maple Creek (S)	W 1/2 9-26-11-W3	
Golden Prairie (S)	NE 1/4 23-26-14-W3	
Eatonia (E)	SE 1/4 21-25-25-W3	
Donavon (G)	NE 1/4 12-9-32-W3	
Biggar (E)	SW 1/4 23-24-35-W3	
Maidstone (E)	SE 1/4 14-23-47-W3	
Marshall (E)	S 1/2 35-26-48-W3	
Dalmeny (E)	NW 1/4 5-7-39-W3	
Osler (E)	NE 1/4 19-4-39-W3	
Waldeck (S)	SE 1/4 36-12-16-W3	
Rush Lake (S)	SE 1/4 9-11-17-W3	drain SE 1/4 10-17-17-W3
Herbert (S)	SE 1/4 33-9-17-W3	
Moose Jaw (Baildon) (E)	NE 1/4 15-26-15-W2	
Davidson (E)	NW 1/4 24-29-26-W2	
Watrous (G)	S 1/2 23-26-30-W2	
Wynyard (G)	SE 1/4 24-17-32-W2	
Balgonie (E)	NE 1/4 28-17-17-W2	
Wolseley (E)	SW 1/4 23-10-17-W2	
Coronach (S)	NW 1/4 19-26-2-W2	
Pambrun (S)	SE 1/4 4-11-12-W3	
Ponteix (S)	NW 1/4 3-13-9-W3	drain SW 1/4 12-9-33-W3
Cadillac (S)	SE 1/4 4-13-9-W3	
Admiral (E)	NW 1/4 2-15-9-W3	
Vidora (S)	NW 1/4 27-26-4-W3	
Consul (S)	NW 1/4 13-27-4-W3	
Govenlock (S)	NW 1/4 9-29-2-W3	
Val Marie (S)	SW 1/4 5-13-4-W3	
Swift Current (E)	NW 1/4 4-16-13-W3	

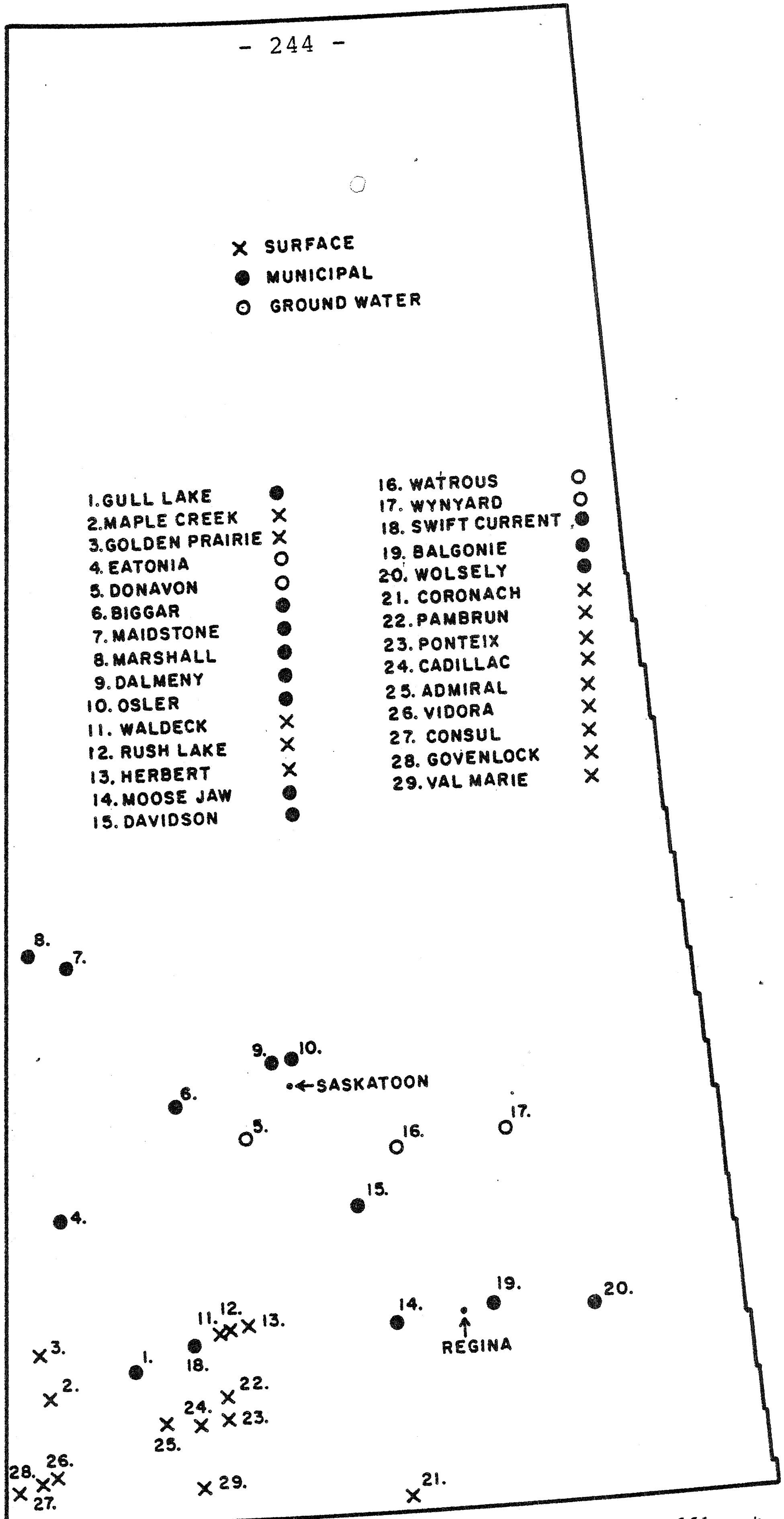

Fig. 1. Surface water, groundwater and municipal effluent irrigation projects in Saskatchewan

Soil samples were take to a depth of 1.2 m at incremental depths of 0-15, 15-30, 30-90 and 90-120 cm. Soil sampling sites were located near the source of the irrigation water and at a point where excess water drained from the land.

Water samples (1 liter) were collected near the inlet of the water to the project and at the drainage outlet (wherever possible). At each point of soil sampling, a group of 10 to 15 plants were collected. These plants were mixed together and sub-samples taken from the whole for analysis. Unfortunately, not all samples were taken at the same stage of growth prior to the first and second cut. The plant samples were ground, mixed and 1 g aliquots were ashed at 470°C and then digested with 0.7 NH_2SO_4 and the digest used for B analysis.

Utilizing standard laboratory procedures, water, soil and plant samples were analysed for boron. In addition, electrical conductivity and pH were measured for both water and soil samples. Results of these analyses are included in Tables 4, 5 and 6.

WATER QUALITY GUIDELINES

(a) Boron

Boron is a constituent of practically all natural waters, in concentrations varying from traces to several milligrams per liter. It is essential for plant growth, but is exceedingly toxic at concentrations only slightly above optimum. Because boron tends to accumulate in the soil even when its concentration in the irrigation water is low, it is necessary to consider this constituent in assessing the quality of irrigation water.

It is known that an appreciable proportion of the boron added to soils as a component of irrigation water is fixed or sorbed by soil materials, with the balance remaining in the soil solution. Because plants respond primarily to the soil solution boron, independently of the amount of boron absorbed by soil, levels of boron in soil solution that can be toleranted by the crop plants is key information in determining criteria for boron content in irrigation water.

Although the literature on plant response to boron is fairly extensive, the number of studies relating boron in irrigation water to soil solution and soil solution to plant response is quite limited. Ultimately, all irrigation criteria for the use of irrigation water high in boron are based upon Eaton's sand culture studies reported in 1935 and 1944 (Eaton 1935, 1944; Scofield 1936; USDA Handbook 60; Wilcox 1960; Alison, 1964; Bingham 1973). Table 2 is one of those applied criteria proposed by Wilcox (1960).

It should be noted that in sand culture studies, because the soils were leached through each day with more than 100% of pore volume, the soil solution concentrations were almost identical with irrigation water concentrations. Also, the technique used assured that all roots were exposed to the same level of boron concentration, thus reducing ambiguity in the results. In the natural system, the concentration of the soil solution in the profile is not uniform. Applying results obtained from sand culture to field conditions requires knowledge of the boron distribution in the profile and as well the plant's response to changes of boron in soils.

Table 2. Limits of boron in irrigation water for sensitive, semi-tolerant, and tolerant crop species based on toxicity symptoms observed on plants grown in sand culture

Sensitive 0.3-1 ppm boron	Semitolerant 1-2 ppm boron	Tolerant 2-4 ppm boron
Citrus	Lima bean	Carrot
	Sweet potato	
	Oat	Turnip
		Onion
	Corn	
	Wheat	Alfalfa
	Barley	
Apple		
	Field pea	Sugar beet
Navy bean		
Jerusalem artichoke		
	Potato	

In each group the crops are arranged in descending order of tolerance within the range indicated.

Theoretical analysis indicates that at equilibrium condition, the boron concentration of the soil solution in an irrigated land would increase gradually from a low level close to that of the irrigation water at the soil surface to a considerably higher value at the bottom of the root zone, determined primarily by the leaching fraction. It was found that plant boron uptake was influenced by the extent of root surface that was exposed to a given boron concentration. Thus, it appears that the best way to relate the boron concentration of the soil solution to the relative crop yield obtained from sand culture experiments is to use the average boron concentration weighted with respect to the relative amount of root present in each depth segment within the root zone. In general, the average boron concentration of the soil solution obtained by this manner would be about 1.5 to 2.5 times higher than that of irrigation water when applying leaching fraction between 0.4 and 0.1.

Despite the fact that Eaton's sand culture studies remain the basis for boron limits in irrigation waters, deficiencies in experimental method makes interpretation of the data controversial. For instance, based on Eaton's work, Wilcox (1960), Alison (1964) and USDA Handbook 60 (1954) all recommend a boron concentration of 3 mg/l in irrigation water for alfalfa, whereas Rhoades (1979) has suggested an irrigation water concentration of 4 mg/l at a leaching fraction of 0.3. Cameron (1979) and Leyshon (1980) after reappraising Eaton's work have suggested that alfalfa will tolerate boron concentration in the soil solution up to 15 mg/l. There is an urgent need for further sand culture studies to be carried out using modern cultivars and with adequate replication in order to better pinpoint crop boron tolerance levels.

Crop species differ widely in tolerance to boron; some plants, i.e., alfalfa, are benefited by boron concentration high enough to injure sensitive plants (e.g., cereals). Owing to adsorption characteristics, irrigation water containing marginal levels of boron may not immediately be toxic. But after prolonged irrigation with such water, the equilibrium will generally be reached where the soluble boron levels will equal or exceed those of the irrigation water. When this has occurred, plants more tolerant of boron must be grown or the soil must be reclaimable. Before establishing permissible boron limits in irrigation waters, the long-term utilization of irrigated land needs to be taken into consideration. Prolonged use of water containing boron levels exceeding 3 mg/l is not generally recommended.

(b) Salinity

The total salt content is the single most important criterion for evaluating irrigation water quality. However, all crop tolerance data are based on the salinity of the soil solution in the root zone, and these data are applicable to specific crops. The salinity of the soil solution reflects the osmotic pressure of the soil. As osmotic pressure increases, so does the osmotic pressure in the cell sap (Russell 1973). Because osmotic pressure is difficult to measure and electrical conductivity (EC) has been found to be approximately related to osmotic pressure, EC is usually used to measure osmotic effects.

In general, water quality evaluations may be approached by analysis of the environmental setting of the project in context and the predicted future water use on the following basis (Fireman 1960): (a) an initial determination should be made of the levels at which a particular soil can be expected to equilibrate with a predicted irrigation water applied. Such an evaluation requires appraisals of salt tolerance of the crops to be grown, water transmission characteristics of the soil, climatic conditions (particularly as related to evapotranspiration), anticipated quality of groundwater levels, depth at which groundwater levels are to be controlled, and fundamental soil properties (particularly those influencing water transmission under both saturated and unsaturated conditions); (b) prediction of anticipated levels at which exchangeable sodium will equilibrate with applied irrigation water. This will involve appraising changes in the water quality over time, soil characteristics (particularly clay mineralology), the possibility of calcium carbonate precipitation in the soil, the ability of salts to rise from the groundwater, plus other essential factors such as climate, cropping systems, and anticipated irrigation practices; (c) determination of influences of toxic ions on crops. This could involve determination in the soil and the water for such elements as boron, lithium, chloride and selenium. This appraisal would require toxicity levels of the ions to the tolerance levels of the crops to be grown in the project area.

Thus, the determination of the suitability of water involves the integration of land and water factors. Table 3 shows some general limits for salinity and permeability effects (Ayers and West 1976).

Table 3. Guidelines for interpretation of water quality for irrigation (Ayers and West 1976)

Irrigation Problem	Degree of problem		
	No problem	Increasing problem	Severe problem
SALINITY (affects crop water avail.)			
Ecw (mmhos/cm)	0.75	0.75-3.0	3.0
PERMEABILITY[1] (affects infiltration rate into soil)			
Ecw (mmhos/cm)	0.5	0.5-0.2	0.2
adj. SAR			
Montmorillonite (2:1 crystal lattice)	6	6-9	9
Illite-Vermiculite (2:1 crystal lattice)	8	8-16	16
Kaolinite-sesquioxides (1:1 crystal lattice)	16	16-24	24

[1]Values presented are for the dominant type of clay mineral in the soil since structural ability varies between the various clay types (Rallings 1966 and Rhoades 1975). Problems are less likely to develop if water salinity is high; more likely to develop if water salinity is low.

QUALITY OF SURFACE WATER USED IN IRRIGATION PROJECTS

The boron content of the water used in the projects (Table 4) in general can sustain the growth of sensitive crops. The only exception is the project located at Coronach. Water used for irrigation in this project contained an average boron content of 1.68 mg/l which is suitable for short-term irrigation of semi-tolerant crops such as wheat, oats and barley. For long-term irrigation, the water is more suitable for growing alfalfa. Except for the Coronach project, all other surface water supplies used for irrigation contained less than

Table 4. Water quality, soil and plant analysis for surface water projects in Saskatchewan

Location	Water quality			Soil analysis									Plant analysis	
				EC							Boron		Boron	
	pH	EC	B	0-15	15-30	30-60	60-90	90-120	Weighted Mean	pH	Paste	EXT	1st cut	2nd cut
		mmhos/cm	mg/l	mmhos/cm							mg/l		μg-gm	
Val Marie	7.7	0.54	0.11	6.2	9.9	12.2	10.9	9.1	9.7	8.2	0.5	3.6	114	47
Pambrun	7.8	0.33	0.39	1.8	2.1	4.3	3.9	4.8	3.4	7.7	0.3	2.5	70	26
Govenlock	7.5	0.42	0.33	0.9	0.8	1.1	3.2	5.3	2.3	7.9	0.4	2.2	67	25
Consul	7.7	0.44	0.12	1.9	1.5	2.0	1.7	3.6	2.1	7.9	0.3	2.0	85	43
Maple Creek	8.2	0.65	0.43	5.0	7.2	10.7	9.9	7.9	8.1	7.9	0.7	3.6	86	31
Vidora	8.1	0.44	0.16	2.0	2.2	5.8	6.4	5.9	4.5	8.0	0.6	2.3	336	155
Golden Prairie	9.0	4.16	1.16	5.6	5.3	7.1	8.0	9.2	7.0	8.0	0.4	2.4	63	67
Admiral	8.7	1.16	0.58	0.7	0.7	1.2	2.9	3.9	1.9	7.8	0.2	1.1	47	46
Cadillac	8.4	1.51	0.64	0.7	0.9	1.7	0.9	0.8	1.0	7.7	0.07	0.78	190	20
Coronach	8.9	1.92	1.68	0.9	0.6	0.6	1.3	2.8	1.2	7.9	0.17	1.65	91	181
Rush Lake	7.9	0.58	0.41	5.4	8.6	10.9	10.4	10.2	9.1	7.9	0.38	2.6	76	64
Ponteix	7.6	0.61	0.39	3.2	4.4	8.0	6.5	6.3	5.7	7.8	0.37	2.2	95	35
Waldeck	8.0	0.57	0.40	0.9	0.6	0.7	0.7	0.9	0.8	7.7	0.16	1.29	89	62
Herbert	7.8	0.55	0.35	1.4	1.7	2.7	3.1	6.2	3.0	7.7	0.17	1.31	72	185

1 mg/l of boron. The above average boron content of water used in the Coronach project can be attributed to the naturally high boron deposits that are found in the area.

With respect to salinity, most irrigation projects utilizing surface water supplies (Table 4) had a level that is well within acceptable limits. Out of 14 projects in this category in the province, 10 projects have a water quality that falls within a range of EC that is less than 0.75 mmhos/cm. The irrigation project at Golden Prairie utilizes irrigation water that has a TDS that is above the desirable limit. The remaining projects at Coronach, Cadillac, and Admiral were in the range where salinity can pose a threat unless good management practices are adopted.

GROUNDWATER IRRIGATION PROJECTS

There are only three groundwater irrigation projects in the province located at Donavon, Watrous and Wynyard that are being operated under special permit. The boron level at all three projects is within acceptable limits and was suitable for use in irrigation. However, in areas where natural boron deposits may exist, it is expected that the boron content of groundwater may be high. Consequently, groundwater quality is site specific.

The TDS level of the water used in these projects range from 1132 to a high of 2572 mg/l. As indicated in Appendix A, the water quality of the Watrous project (2572 mg/l) requires careful management and good drainage if it is to be used to successfully produce an agricultural crop.

A detailed review of groundwaters in Saskatchewan (Bachman et al. 1980), indicates that most groundwater formations that have an abundant supply of water for irrigation are not of good quality. Consequently, groundwater irrigation in the province is limited to site specific situations where all criteria for irrigation with poor quality water are met.

MUNICIPAL EFFLUENT PROJECTS

Currently, 12 projects are being operated in the province. The projects at Marshall and Davidson were the only two projects that boast a boron content above 1 mg/l. As indicated by Wilcox (1960) who conducted studies using sand culture, semi-tolerance crops can be successfully grown with this type of water.

The TDS of the water used ranges from 652 to 2400 (Table 6). Since most effluent water is stored in evaporative lagoons, the concentration of salts is naturally higher than the raw water supply. In addition, many of the water supplies are derived from groundwater. The irrigation project at Marshall utilizes the poorest quality water in the province; the next worse, the project at Swift Current. Detailed research conducted by Agriculture Canada (Jame et al. 1981) indicates that with good management practices, a good crop of alfalfa can be grown with municipal effluent with a minimal amount of yield reduction due to salinity.

SURFACE WATER IRRIGATED SOILS

The levels of soluble boron in surface water irrigated soils were generally well below acceptable limits (Table 4). Soils in those irrigated projects can support even the most sensitive crops that can be grown in the province. For some soils, the question is one of deficiency rather than toxicity.

Irrigation water always contains dissolved salts, and in most cases more salts are added to the land in the irrigation water than are taken up by the crop (Russell 1973). In regions where there is sufficient rainfall during some period of the year for water to leach the soil profile, the salts left behind from the irrigation water will be leached out. Thus if irrigation water contains 500 mg/1 dissolved salts and if 50 cm of irrigation water are used to irrigate a crop, the water will add 2½ tons of salt per hectare during the growing season. Consequently, irrigation schemes must be managed to prevent an excessive accumulation of salts in the root zone.

With good management practices, the equilibrium salt content of soils should be equivalent to TDS of the irrigation water. Consequently, water quality criteria listed in Table 3 serves as a guide to assess irrigated soils.

A review of the 14 surface water projects indicates that salinity could be a problem on half of the 14 surface water projects when the average EC of the soil profile is greater than the incoming water or 1.5 mmhos/cm. Projects located at Vidora, Pambrun, Govenlock, Consul, Golden Prairie, Admiral and Ponteix fall in this category. These projects are located on heavier textured soils where drainage and infiltration are a problem. As a result, without adequate drainage, yields of forages may be reduced under these soil conditions.

GROUNDWATER IRRIGATED SOILS

The boron levels of soils in the three groundwater irrigated projects were very low. Consequently, for surface water projects, a problem of deficiency may exist initially until the boron levels build up from repeated irrigation.

The three groundwater irrigation projects which are relatively new and located in areas of good drainage have a salt level that is considerably less or equal to the irrigation water being used. Consequently, it is expected that salinity will not be a potential problem unless a high water table results causing salt accumulation at the surface.

EFFLUENT IRRIGATED SOILS

The soluble boron fraction (paste B) was well below toxic limits for all projects. Consequently, in the short term the soils in the projects can support the most sensitive crops that can be grown in Saskatchewan. Depending on uptake, a buildup of boron levels may occur on the effluent projects in due time. However, since alfalfa is normally grown on these projects, the buildup is highly unlikely. Salinity is unlikely to be a problem on 5 of the projects in the province. Eatonia, Maidstone and Gull Lake followed by Marshall, Davidson, Balgonie and Swift Current have soils whose salinity levels range from high to moderately high. In these projects, when salinity levels were above an EC of 3, the EC of the water is lower than that of the soil. This suggests that insufficient leaching is provided for in the management practice.

Long-term studies at Swift Current (Jame et al. 1981) suggest that salinity levels can be controlled by applying a leaching fraction of 15% without significant yield reduction. Consequently, it is imperitive, on projects where salinity is a potential problem, to provide sufficient external drainage so that sufficient leaching can be provided to maintain an equilibrium between the salt level of irrigation water and that of the soil.

PLANTS

Boron moves to the root surface in the soil solution primarily be mass flow and translocates readily through the xylem in the transpiration stream. It accumulates principally in the leaves where it becomes one of the least mobile of the micronutrients. As a result, boron accumulation in the leaf tends to increase with leaf age.

Boron can be unevenly distributed within the leaf. The margins of corn leaves have been found to contain 4 to 5 times that found in whole leaves and some workers have found that necrotic areas within a leaf can contain 1500 ppm B. The lack of uniform distribution within the plant has had serious consequences for plant analysis though only limited attempts have been made to standardize sampling recommendations when toxicity is suspected. In general, dicotyledons contain more boron than monocotyledons and this reflects not only the need of various species for boron, but also reflects their relative tolerance to high levels of boron. Alfalfa and the Brassicae have the highest response, the highest requirement and the highest tolerance to boron. Because of this variability in response between species and because it is the most common irrigated crop grown in Saskatchewan, only alfalfa was sampled at each site.

For most species, deficiencies in the field occur when the boron level is less than 15 ppm in the dry matter and adequate boron occurs from 20 to 100 ppm. Boron toxicity generally occurs when plant tissue exceeds 200 ppm. These are, of course, just guidelines. Sensitive crops such as cereals may exhibit toxic responses at lower levels and will not show deficiency symptoms at very low levels of boron. Generally, healthy legumes like alfalfa contain above 35 ppm. Ohio suggests 21 to 80 ppm in the top 7.5 cm of alfalfa is in the sufficiency range.

The concentration of B that will result in toxicity or deficiency can be markedly affected by the presence of Ca, K or N in the tissue. At high calcium the symptoms of B deficiency are accentuated while the incidence of B toxicity is reduced. The Ca effect also seems to be related to high pH's. Potassium has the opposite effect to that of Ca. High levels of K accentuate B toxicity symptoms, however, low levels do not increase the optimum tolerance level of the plant to B. Boron has been found to have a relationship with N in greenhouse studies but not in the field. There is also evidence for a relationship with Na and Mn.

Using the criteria, our analysis of the plant material, taken at the various sampling sites, did not reveal any evidence of potential B deficiences. All plants analysed had $>$ 15 µg/gm B in their tissue (Tables 4, 5 and 6), except for 12 µg/gm for the second cut of alfalfa at Wynyard. The B concentration in the whole plant at two sites showed evidence of possible B toxicity. These were at Vidora and at Wynyard where B levels in whole plants of the first cut were 336 and 352 µg/gm plant material, respectively (Tables 4 and 6). The B concentration in the irrigation water at these two sites was actually low; however, B concentration in the soil paste from Vidora was 0.6 µg/gm soil, the second highest paste B noted (next to Maple Creek 0.7 µg/gm soil). Plant material from 3 other sites (Coronach, Donovan and Herbert) also showed fairly high values of 137, 136 and 128 µg B/gm plant. It is worth noting that the Coronach site was the one with the highest B concentration in its irrigation water.

SUMMARY

The survey of Saskatchewan irrigation projects, where surface water, groundwater and effluent are being used, indicates that the water quality with respect to boron is acceptable for all types of projects, except for the problem existing at Coronach.

The survey further indicates that salinity poses more of a threat to production under irrigation than any other problem. Some of the old projects operated by P.F.R.A. are located on heavy textured soils where infiltration and leaching are a problem. Consequently, salinity levels have increased in the project to levels for greater than the incoming water. Consequently, the importance of external drainage and leaching cannot be overstressed.

From the plant data we conclude that boron toxicity is unlikely to be a significant problem to Saskatchewan agriculture, except at a

Table 5. Water quality, soil and plant analysis for groundwater projects in Saskatchewan

Location	Water quality pH	Water quality EC	Water quality B	Soil analysis EC 0-15	EC 15-30	EC 30-60	EC 60-90	EC 90-120	Weighted Mean	pH	Boron Paste	Boron EXT	Plant analysis Boron 1st cut	Plant analysis Boron 2nd cut
	mmhos/cm		mg/l			mmhos/cm					mg/l		µg-gm	
Donovan	-	-	-	1.6	2.2	2.4	1.0	1.1	1.7	7.8	0.21	2.01	-	136
Watrous	8.0	4.02	0.96	1.3	1.4	1.3	0.9	1.0	1.2	7.8	0.11	1.03	107	74
Wynyard	8.5	1.77	0.51	0.7	0.4	1.0	0.85	1.14	0.82	7.5	0.26	1.83	352	12

Table 6. Water quality, soil and plant analysis for municipal effluent projects in Saskatchewan

Location	Water quality pH	Water quality EC	Water quality B	Soil analysis EC 0-15	EC 15-30	EC 30-60	EC 60-90	EC 90-120	Weighted Mean	pH	Boron Paste	Boron EXT	Plant analysis Boron 1st cut	Plant analysis Boron 2nd cut
	mmhos/cm		mg/l			mmhos/cm					mg/l		µg-gm	
Gull Lake	7.6	1.02	0.68	2.0	2.2	4.1	7.1	7.3	4.5	7.9	0.44	2.44	96	25
Balgonie	8.3	1.89	0.64	1.0	1.0	1.7	4.4	8.3	3.3	7.6	0.23	2.04	67	44
Davidson	8.4	2.50	1.36	2.7	2.3	5.1	3.8	2.7	2.7	7.8	0.30	2.28	65	56
Wolsely	8.8	1.75	0.64	3.1	1.9	3.0	2.5	2.1	2.5	7.6	0.18	1.75	61	47
Biggar	-	-	-	0.7	0.6	0.6	0.9	0.9	0.8	7.3	0.11	1.13	65	95
Osler	8.2	0.71	0.64	1.1	0.8	1.6	0.7	0.5	1.0	7.5	0.17	1.80	49	65
Eatonia	-	-	-	3.6	5.1	4.8	5.2	5.6	4.8	7.7	0.23	2.03	94	110
Maidstone	8.6	1.42	0.52	5.9	5.0	4.8	4.7	4.5	5.0	7.7	0.23	2.13	76	66
Dalmeny	8.8	0.93	0.70	0.7	0.5	0.5	0.7	1.2	0.7	7.2	0.09	0.78	62	67
Marshall	9.3	2.78	1.56	0.9	0.7	3.9	5.7	7.1	3.7	7.3	0.15	1.85	36	46
Moose Jaw	8.0	1.11	0.46	0.9	0.7	0.8	0.8	0.8	0.8	7.0	0.29	1.57	72	70
Swift Current	-	2.50	0.57	2.4	1.9	2.2	2.4	2.6	2.3	-	-	-	-	-

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few isolated locations. As was pointed out in the discussion of soil and water quality, total dissolved solids are a more immediate problem and it is likely that if the salt accumulation problems are solved then any potential for boron toxicity will also be removed.

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