THE EFFECT OF THREE DIFFERENT CROP ROTATIONS ON A SALINE SOLONETZIC SOIL OVER A PERIOD OF FIVE YEARS

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INTRODUCTION

The problem of soil salinity was not unknown to early settlers of the semi-arid to arid Northern Great Plains region nor to early soil scientists in Saskatchewan and elsewhere. By the early 1950's scientists had documented an estimated 400,000 ha of saline soils (Rennie & Ellis 3). By 1976 Crossen (1) estimated a four-fold increase of salt-affected soils in Saskatchewan to over 1.6M ha.

To some degree the reason for this increase is a greater awareness and recognition of the problem by farmers, assessors and scientists alike. Government policy, which based grain quotas on cultivated acres, resulted in the breaking up of marginal, in many cases saline, land which otherwise might have remained virgin and its salt problem hidden. However, it is generally agreed that the main reason for the rapid spread of soil salinity during the past 3 decades lies in the farmers tilling of the soil.

By the early 1970's the severity of the problem became increasingly apparent resulting eventually in the Saskatchewan Department of Agriculture developing and coordinating a program designed to demonstrate possible corrective measures and to try and discover new facts about the problem. Agriculture Canada, especially its research station at Swift Current and the Saskatchewan Institute of Pedology at the University of Saskatchewan cooperated and continue to do so in this program.

MARRIOTT EXPERIMENTAL SITE

In an attempt to obtain additional information on the effect which various crop rotations may have on the salinity of the soil, a number of saline areas, preferably saline seep in nature, were located in the province. The owners of these areas were asked to establish 3 or 4 different rotations on the chosen field, the effect of which were then to be measured by scientists participating in the program.

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One such area, although not seep in nature, is located on the N.E. quarter of Sec.16 - Twp.32 - Rge.14 - W3, near the small hamlet of Marriott. The soil map indicates the area to be a complex of Bradwell orthic dark brown Chernozemic and Hanley dark brown Solonetzic soils. (Ellis, Acton & Moss 2). In actual fact the area is predominantly saline solonetzic in nature, of a medium to moderately fine texture and borders a rather large salinized aluvium depression.

EXPERIMENTAL PROCEDURE

Figure 1 diagramatically illustrates the layout of the three crop rotations; continuous barley, barley-summerfallow and permanent forage, on an area just over 20 ha in size. The area was chosen in the spring of 1975. Prior to the harvest of that year, 4 sites on each rotational treatment were selected at which soil characteristics would be monitored over a period of years. By placing large white stakes on either edge of the area and in line with each of the 4 sets of sites, it was possible to return to the monitoring sites each fall for sampling. This is of critical importance when dealing with the well-known variable nature of the salinity problem.

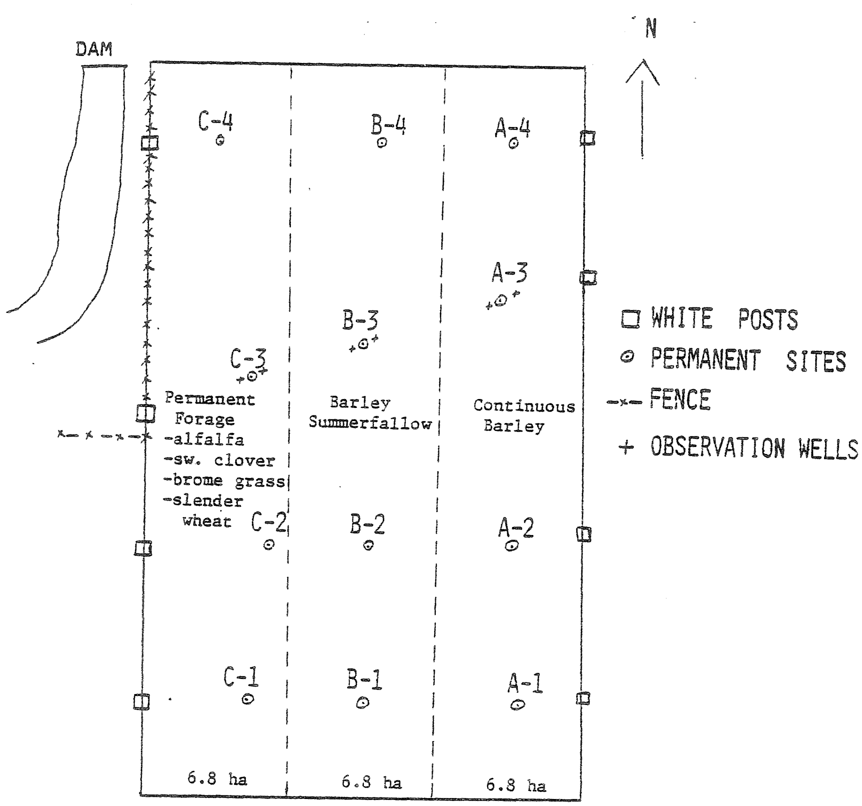

FIGURE 1. DIAGRAM OF MARRIOTT SITE (NE 16-32-12-W3)
SHOWING CROP ROTATIONS AND
PERMANENT SITES MONITORED

The entire area had been in summerfallow during the summer of 1974 and was seeded to barley in the spring of 1975, fertilized with 65 kg/ha of 11-48-0. In the fall of 1975, just before freeze-up, the west third, Field C, of the area was seeded to a mixture of sweet clover, alfalfa, brome and slender wheat grass. In subsequent years the center third of the area, Field B, was alternatively summerfallowed and seeded to barley fertilized with approximately 25 kg/ha of P_2O_5. The east third of the area, Field A, was seeded to barley each year and fertilized with 100 to 110 kg/ha of 23-23-0.

Observation wells 1.8m and 3.3m deep were installed at permanent monitoring (PM) sites A-3, B-3, and C-3 in the fall of 1977 and thereafter checked in spring and fall to determine the depth to the water table. At no time did the water table in any of the wells measure less than 2.85m from the surface. Water samples obtained in November, 1977 had conductivity readings of about 4 mmhos/cm, whereas, the one sample of water obtained in June, 1978 had a conductivity reading of 12.4 mmhos/cm.

Each fall $2m^2$ of crop were harvested at each of the PM sites of the fields in barley. Forage yields of Field C were obtained from the farmer's record of number of bales harvested.

Between harvest and freeze-up of each year, four cores were drilled 1.8m deep in an area approximately 5m across at each of the PM sites. The four soil cores were composited at depths of 0-15, 15-30, 30-45, 45-60, 60-90, 90-120, 120-150, and 150-180cm, and analysed for salt concentrations using the saturated paste extract method. The Na^+, Mg^{++}, Ca^{++}, K^+ cation and Cl^- anion concentrations of the extract were also measured as was the pH of the paste.

RESULTS AND DISCUSSION

Figure 2 illustrates the change in soil salinity over the 5-year period at each of 3 depths, 0-60cm, 60-120cm, and 120-180cm, for each of the three treatments. Analyses of variance data indicated that at the 0-60cm depth the interaction between the 3 treatments over the period of 5 years approached significance (F value significant at .075).

From the graph it can be noted that the soil salinity of the barley-summerfallow treatment at the 0-60cm depth remained fairly constant over the 5-year period; decreasing slightly during the fallow years (1976 and 1978) and increasing slightly during the cropped years (1977 and 1979). This would be in agreement with data reported by Sandoval and Benz (4,5) and to some extent with observations made as a result of fertilizer trials conducted on the same fields which frequently showed slight increases in surface soil salinity during the cropping year.

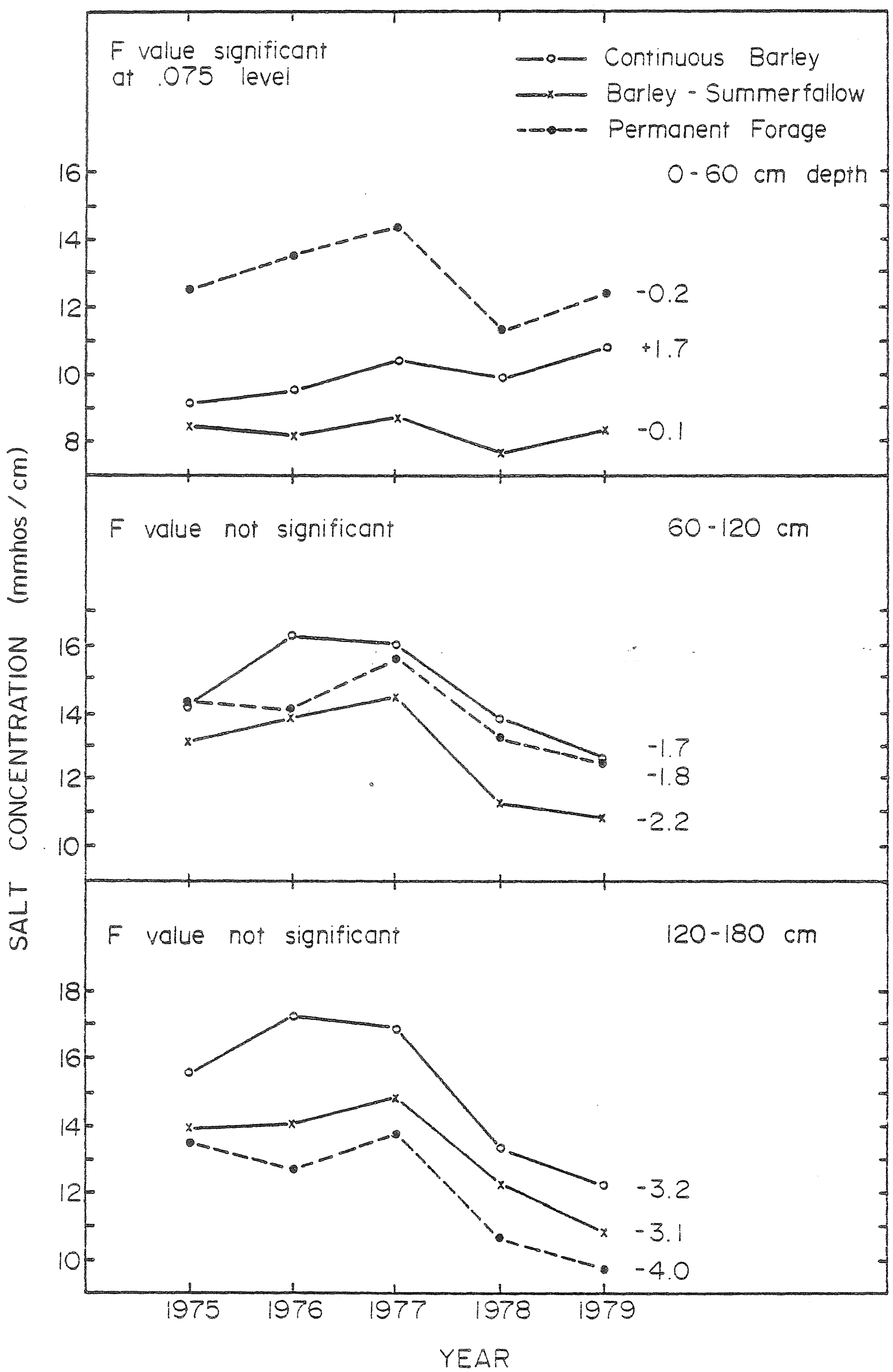

Figure 2. The effect of three crop rotations on the salt concentration at three depths of soil over a period of 4 years. (Mariott).

Under the continuous barley treatment, the soil salinity of the 0-60cm depth increased gradually but substantially during the 4-year period; that of the permanent forage crop increased markedly for two years then dropped sharply in the third year and rebounded in the fourth year to about the level in 1975.

A closer look at the top 60cm (Figures 3a,b&c) reveals some additional interesting information. The continuous barley and barley-summerfallow rotations increased the salinity levels of the 0-30cm depth by 3.7 and 2.4 mmhos respectively. The salinity concentration pattern of the 30-60cm depth under continuous barley (Figure 3a) followed the pattern at greater depths quite closely and at the end of the fourth year was only 0.3 mmhos/cm less than in 1975. It would appear then that the increased salt concentration of the 0-30cm depth came from below the 30-60cm depth.

Under the summerfallow-barley rotation, the salinity concentration pattern of the 30-60cm depth (Figure 3b) decreased gradually over the 4-year period ending up 2.6 mmhos/cm lower than to begin with. This is almost identical to the 2.4 mmhos/cm increase in the 0-30cm depth and would indicate that the salt movement was primarily between these two depths.

The salt concentration pattern under permanent forage is considerably different in that there was a sharp reduction in the salt concentration of the 0-30cm depth (Figure 3c) during the second and third years followed by an inexplicable increase during the fourth year.

The decrease during the first 2 years was more than accounted for by a very sharp increase in the salt concentration of the 30-60cm depth. However, during the third and fourth year the salinity levels of this depth dropped sharply as did that of the lower depths. Whether the forage crop had penetrated the Bnt horizon sufficiently by that point in time to allow for a large flush of water and salts through it is open to debate. Site C-4 was considerably different than all other permanent monitoring sites and could also have caused this somewhat different pattern of salt movement.

At lower depths (60-120cm and 120-180cm) the pattern of salinity changes over the 4-year period was not significantly different between the 3 treatments. Almost without exception there was a gradual increase in soil salinity in 1976 and 1977 followed by sharp decreases in 1978 and 1979.

Comparing the changes in average salt concentration to depth of sampling (180cm) over the 4-year period under each of the three crop rotations (Table 1), one finds that overall reductions in salinity were 1.0, 1.8 and 2.0 mmhos/cm for the continuous barley, summerfallow-barley, and permanent forage rotations respectively. Results from similar experiments at Landis and Glenside show identical patterns.

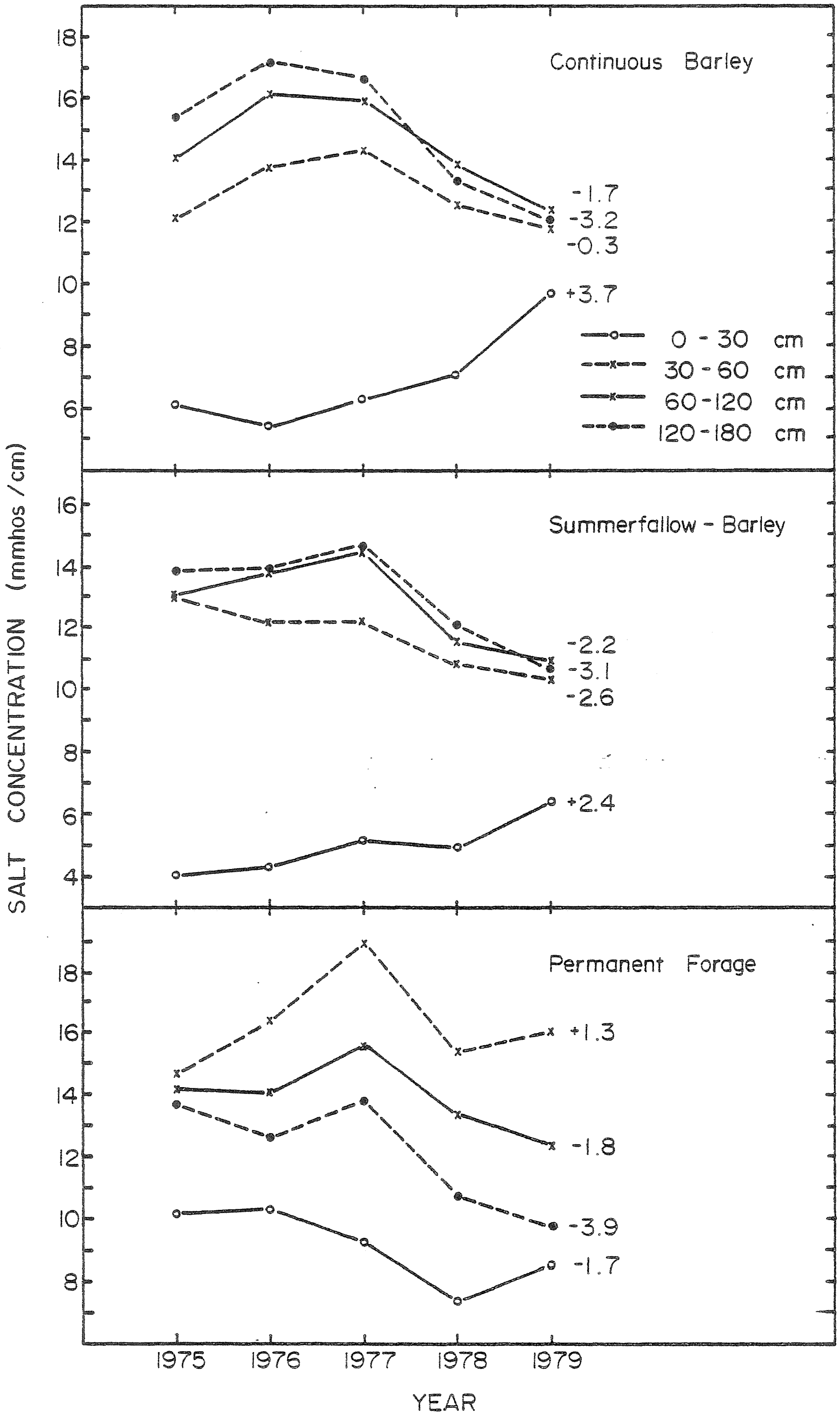

Figure 3. Changes of salt concentration at 4 depths over a period of 4 years under the various rotations; Continuous Barley, Summerfallow - Barley, Permanent Forage.

TABLE 1 CHANGES IN SOIL SALINITY (MMHOS/CM) TO A DEPTH OF 180CM UNDER 3 DIFFERENT ROTATIONS AT 3 LOCATIONS IN SASKATCHEWAN 1975-79

		ROTATION		
LOCATION		PERMANENT FORAGE	SMF.-CROP	CONT. CROP
MARRIOTT	1975	13.5	11.8	12.9
	1979	11.5	10.0	11.9
	DIFF.	-2.0	-1.8	-1.0
LANDIS	1975	10.3	8.6	10.7
	1979	8.3	7.1	9.4
	DIFF.	-2.0	-1.5	-1.3
GLENSIDE	1976	15.5	14.2	12.5
	1979	13.4	12.9	12.0
	DIFF.	-2.1	-1.3	-0.5

Why the continuous barley rotation and the permanent forage rotation should cause such a different change in salt concentration is hard to explain except for some of the comments regarding the latter rotation made earlier. It is of interest though to note that considerable more salt must have disappeared from the summerfallowed field than from that continuously cropped.

Moisture contents on an air dry basis were determined for all samples in 1978 and 1979, and are shown for 3 depths plus an overall average in Figure 4. Since this information was not determined in earlier years, its usefulness is somewhat limited. It is of note, however, that the moisture level of the 0-45cm depth under the continuous barley rotation in the fall of 1978 was only marginally lower than that under the summerfallow rotation. When moisture levels were determined in the spring of 1979 in connection with fertilizer trials it was determined that the two fields had moisture levels in the 0-60cm depth of 16.8 and 16.2 percent respectively; rather remarkable after 4 years of cropping. The lower moisture content in the 0-45cm depth in 1979 under summerfallow barley as compared to that under stubble barley can probably, in part, be attributed to the much better barley crop on fallowed as compared to stubbled land (see Table 2).

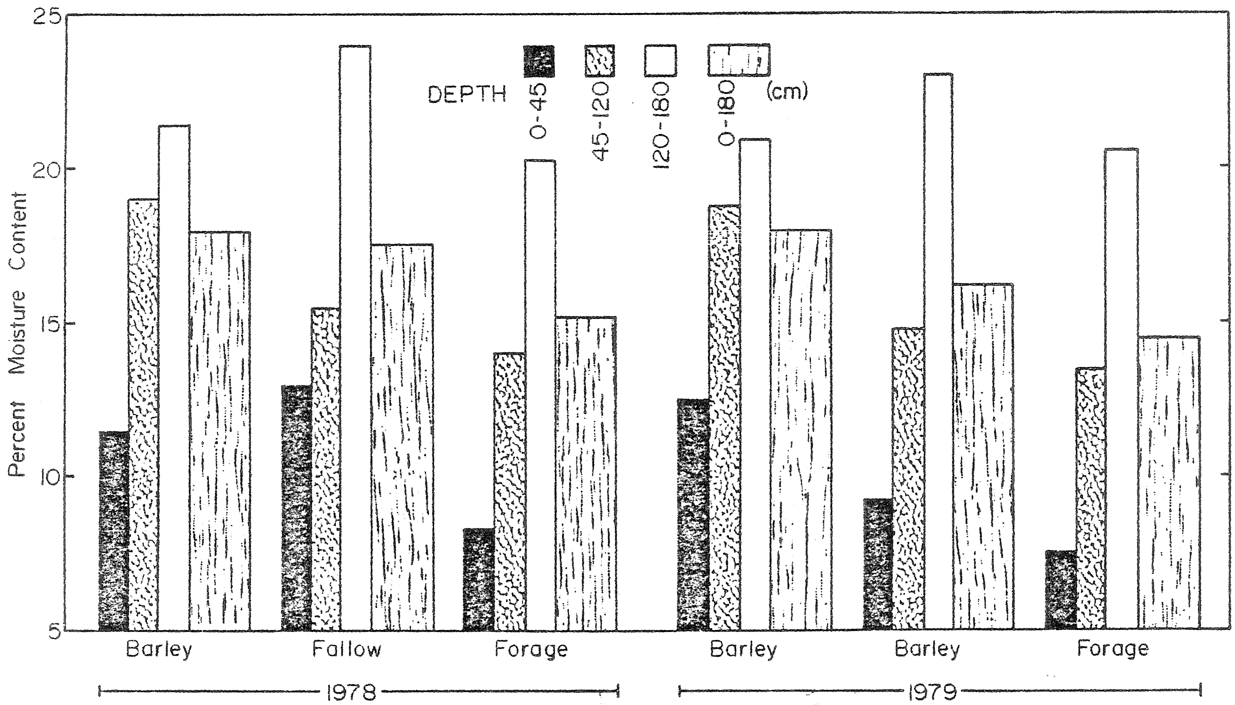

Figure 4. Soil Moisture Content at various depths in the 4th and 5th year of three different crop rotations.

TABLE 2 YIELD OF BARLEY AT PERMANENT SITES - MARRIOTT, 1975-79

YEARS	GROWING SEASON PRECIP- ITATION	FALL ELECT. COND.# 0-60 CM FALLOW	STUBBLE	BARLEY YIELDS# FALLOW	STUBBLE	FALLOW / STUBBLE
	MM.	MMHOS	MMHOS	KG/HA	KG/HA	RATIO
1975		8.5	9.1	1299	1807*	
1976	194	8.2	9.7		1337	
1977	179	8.7	10.3	1847	1268	1.46
1978	118	7.7	9.9		844	
1979	122	8.4	10.8	1095	501	2.19

\# AVERAGE OF 4 SITES

* ALSO FALLOW YIELD

Looking at the overall moisture content to depth of sampling (180cm) one notices that the permanent forage field is driest with the continuous barley being most moist. One should, however, not jump to any conclusions here since the 4 sites selected in 1975 for the permanent forage site could very well have been driest even at that time. The change in moisture content would have been the desirable information but regretably is not available.

Table 2 shows the yield of barley over the 5-year period as estimated by $2m^2$ samples taken at each of the 4 permanent monitoring sites per treatment. The 1975 difference in yield between the fallow and stubble column is difficult to explain since the entire area was fallowed in 1974.

Of special note, is the rapid decrease in stubble yield over the 5-year period from 1807 to 501 kg/ha. The ratio of fallow to stubble yield changed from 1.46 in 1977 to 2.19 in 1979. An immediate reaction would be to ascribe this change to the difficulty of maintaining stubble yields under the dry conditions which were experienced in 1979. It must be noted, however, that, based on 20 sampling sites, there was no significant difference in the moisture content to 60cm at seeding time between the two fields. The moisture contents on an air dry basis were 16.8 and 16.2 respectively for the stubble and fallow fields.

Competition from a heavy infestation of weeds, primarily Russian thistle, more than likely was a major factor. Poor control measures applied in 1978 caused an extremely heavy growth of Russian thistle in the spring of 1979 which, although controlled reasonably well, no doubt influenced yields negatively. The increased surface salinity of the PM sites of the continuous barley field by 3.7 mmhos/cm could also have contributed to the lower yields.

Further detailed analysis of the financial feasibility of continuous cropping a saline solonetzic soil is not within the scope of this paper and would be unwise in view of the limited number of monitoring sites and their specific nature. Suffice it to conclude that both the data in Figure 3a showing an increase in soil salinity of the 0-30cm depth under continuous barley production and the yield data presented in Table 2, dictate against recommending such a practice under the conditions experienced over the 4-year period in question, and for the type of soil experimented with. Such a conclusion may appear to be in direct contradiction to the now common recommendation to reduce summerfallow as a means of controlling soil salinity. In a way it is and in a way it isn't.

Under arid and semi arid conditions, summerfallowing, based on the data presented here and by others (4, 5), may lead to a reduction in the salinity of the field in question. However, the salts leached downward in the process could very well find themselves discharged in a saline seep area at lower elevations.

It may therefore be suggested that the data presented here does in fact support the common notion that excessive summerfallowing contributes to the increasing salinity problem. However, frequently it is not the field being summerfallowed that is in danger but rather discharge areas at lower elevations often many kilometers away. Therefore, the data also points out the need to be more specific in our recommendations. The reduction in summerfallow acreage has to be recommended in the recharge areas of a farm or the province; in areas presently to a large degree not experiencing the saline problem. Where the recharge and discharge areas are farmed by the same individual such a recommendation may in time be accepted. However, to affect a major change in the cropping practices of farm operators in upland areas with the argument that someone at lower elevations some distance away is suffering will continue to be no small challenge.

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