IMPACT OF MACRONUTRIENTS ON CROP RESPONSES AND ENVIRONMENTAL SUSTAINABILITY ON THE CANADIAN PRAIRIES

A Review of the

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Foreword

Fertility research has a long and productive history in western Canada dating back to the early 1900s. The knowledge base that has been generated has allowed our producers to increase their production efficiencies and lower their costs. The increase in efficiency has also allowed our producers to limit the impact of their farming practices on the environment. Some would suggest that our quest for increased efficiency in production has been at the expense of the land and the detriment of the environment. There is a growing feeling that commercial fertilizers and other farm chemicals are harmful to the land resource base and to the food produced. Such claims have not been supported by the scientific data generated in western Canada over the past several decades. On the contrary, years of fertility research have demonstrated the positive role fertilizers play in maintaining soil quality and productivity and in preventing land degradation. Our land resource must be maintained and even improved if western Canadian agriculture is to be environmentally sustainable and profitable. This does not mean that there are not further questions to be answered, nor does it mean that further improvement in nutrient efficiencies can not be realized.

This bulletin documents the impact of N, P, K and S research on crop productivity and environmental sustainability on the Canadian prairies. Agricultural research repays by up to 200% every dollar invested but some feel that new technology remains on the researcher's shelf. One of our major goals was to compile, organize and interpret the published literature on N, P, K, and S nutrient technology. We also looked at unpublished files of a select number of senior researchers to verify whether a significant amount of R&D had not been made public. The authors of the following 12 chapters were required to assess not only the impact of available research on crop production but also on environmental protection of the soil and water and the quality of food.

We feel that this bulletin will be of substantial technical interest to researchers as they continue to unravel the principles of soil fertility and fertilizer technology. It will perhaps be of greatest strategic value to research managers and funding agencies in assisting them to establish research priorities and to allocate funding accordingly.

The N, P, K, S research reported in this bulletin would appear in general to have been quickly incorporated into extension publications such as the Guide to Farm Practice in Saskatchewan and is reflected in the recommendations made by the various soil testing laboratories on the prairies. This does not mean that all new findings are quickly adopted by farmer managers, but it does mean that fertility research has served us very well in the past and we must make sure that it continues to do so in the future if western Canadian producers are to continue to produce safe, nutritious food at competitor prices for an ever-increasing world population. There are questions yet to be answered, gains yet to be made in crop production, and improvements yet to be made in nutrition efficiencies through new understandings of soil fertility and fertilizer technology. For this to be achieved, continued support of fertility research is as essential to agricultural sustainability in western Canada as is the land base itself.

We wish to acknowledge the authors of several chapters for their expertise and views on their assigned topics and to thank them for their generous offering of their time in researching and writing the chapters and also in responding positively to the peer reviews of their manuscripts.

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Abstract of Chapters

The average negative balance of N, P_2O_5 and K_2O on the prairies over the past 25 years is 24, 5, and 18 kg ha^{-1} yr^{-1}, respectively. Estimates of the contribution of fertilizer nutrients to grain production range from a low of 15 to as high as 37% of total production, equivalent to 8.2 to as high as 18.8 million tonnes of grain.

A very significant change has taken place in the P fertility level of prairie soils. Prior to 1970, the probability of obtaining a yield response of 250 kg ha^{-1} was 48% on stubble and 71% on fallow. Since 1970, this probability has declined to 32 and 48%, respectively.

Nitrogen, which during the 1940s and 1950s was seldom considered an important nutrient, now has become the dominant fertilizer nutrient used by farmers. Nitrogen fertility levels in general have declined sharply.

There is no reference made to changing trends in yield responses to K and S, principally because the area of deficient soils remains relatively small even today.

Nitrogen FUE rarely exceeds 50% and is perhaps more commonly in the vicinity of 20%. Mean recoveries of fertilizer N based on 37 well-designed field experiments across the prairies were 38% in the whole plant, 32% remaining in the soil, and 30% lost.

Management practices including soil testing, extended crop rotations, snow trapping, and variable rate fertilization which improved the use of either water or N will in turn enhance the efficient use of applied fertilizer N. Nitrogen source is not necessarily a significant factor determining FUE. In general, under optimum fertilizer management practices all nitrogen sources are equivalent.

The ability of plant roots to take up soil P is aggravated by the marginal amounts of plant available P, low soil moisture and/or low soil temperature. The maximum plant utilization of applied fertilizer P is in the vicinity of 20% and declines sharply from that value depending on fertilizer management practices in particular. Residual fertilizer P, accordingly, is on a relative scale large and is quickly immobilized due to adsorption precipitation and biological reactions. In general, residual P remains relatively highly available from a chemical standpoint, but frequently is positionally unavailable. Most of the phosphorus applied in large

Page

applications, i.e., 200 kg P_2O_5 ha^{-1} or higher, can be expected to be recovered over periods of 10 years or more.

Cultivation has substantially decreased the organic P content of soil. However, conservation tillage and extended cropping systems will rebuild organic P as a part of the new soil organic matter.

The P cycle, P fertilizer management practices and factors influencing plant available soil P, have been extensively researched, yet reasons for the decline in response to applied fertilizer P, the practical significance of organic P, and the large annual fluctuations in sodium bicarbonate extractable P, remains speculative.

Potassium deficient soils occupy approximately 1.4, 0.4, and 0.4 million ha in Alberta, Saskatchewan, and Manitoba, respectively. Soils with severe deficiencies exist in the coarse-textured Black, Dark Grey, Grey Luvisolic and Organic soil orders. The average available K of Luvisolic soils is typically 400 kg K_2O ha^{-1}, while that of a Brown Chernozem is over 1000 kg K_2O ha^{-1}.

Plant available soil K can be precisely measured using dilute ammonium acetate or sodium bicarbonate extractants. A large amount of field research has been conducted on potassium fertilizer management practices.

Approximately 4.0 M ha of cultivated soils across the prairies are deficient and 6.7 are potentially deficient in S. This places sulphur as the third most limiting nutrient to crop production on the prairies after N and P. Sulphur-deficient soils are rare in the Chernozemic soil regions primarily because these soils contain large amounts of ester-bonded sulphates in the soil organic matter. The increase in area of S-deficient cultivated soils noted in the past decade is partly related to the degradation that has occurred in soil organic matter, partly from lower S deposition from the atmosphere, partly to the significantly higher crop yields, and partly to the increased production of high S-requiring crops such as canola.

Strong interactions between N and S have been recorded with canola. A desirable N/S ratio for canola is approximately 7. Both the protein concentration and total yield of oil may be enhanced by the addition of S to crops grown on sulphur-deficient soils. Soil tests offer an effective guide for S fertilizer requirements.

Band application of N has been 30 to 40% more effective than broadcasting in trials concentrated on reasonably well-drained fields. In the more arid regions, where minimal till or direct seeding is more popular, research findings support the application of wide bands of seedrow fertilizer at the time of seeding for spring-seeded cereal crops.

Significant problems continue to restrict the effective use of fertilizers on cereal crops in a minimal till or direct seeding mode. The development of the technology to nest/point inject fertilizers as a means of applying N fertilizer under no-till conditions is theoretically appealing.

Microorganisms can increase the available nutrient status of the soil by direct addition (N_2 fixation), solubilization (P and S), or chelation (Fe) of the nutrients required by plants. Microorganisms also alter the sensitive balance of root diseases and exude plant growth regulators which stimulate both root and plant development. The few commercial microbial products which exist to manipulate the plant rhizosphere are very successful. Rhizobial legume inoculants can result in fixation of 100 kg N ha^{-1}. Phosphorus-solubilizing fungi and biological control agents are in the early stages of having a significant economic impact.

Recent reports from Environment Canada and the Science Council of Canada state fertilizer nutrients damage the environment. To the contrary, research relevant to the issue of N, P, K, and S fertilizers in the environment have shown that these nutrients play an indispensable and key role in the sustainability of western Canadian agriculture. In the prairie environment, maximum economic crop production in fact relies on environmentally sound field management practices including fertilizer application where required.