

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.

eview of Nutrient Status and Fertility Information

Department of Agricultural Economics and Farm Management University of Manitoba Winnipeg, Manitoba R3T 2N2 Review of Nutrient Status and Fertility Information on Manitoba Soils

D. Zbeetnoff and R. Josephson

Department of Agricultural Economics and Farm Management University of Manitoba

TABLE OF CONTENTS

			Page
1.0.	Intro	duction	1
	1.1.	Rationale for Fertilizer Use	ī
		Concepts	ī
		1.2.1. Nutrient Supplying Power	2
		1.2.2. Essential Nutrients	3
		1.2.3. Balanced Nutrition	5
2.0.	Mutrie	ent Status of Manitoba Soils	7
2.0.	2.1.	Nitrogen (N)	8
	2.2.		9
		Potassium (K)	16
		Sulphur (S)	19
	2.5.	Statuses of Other Macronutrients	21
		Micronutrients	28
	2.0.	2.6.1. Copper (Cu)	29
		2.6.2. Zinc (Zn)	31
		2.6.3. Manganese (Mn)	35
		2.6.4. Iron (Fe)	37
		2.6.5. Boron (B)	37
		2.6.6. Molybdenum (Mo)	39
		2.6.7. Other Micronutrients	39
3 0	Accec	sment of Nitrogen Fertility Requirements in Manitoba	41
5.0.	3 1	Soil Reserve N	42
	3.1.	3.1.1. Mineralization of Organic Matter	44
		3.1.2. Nitrogen Fixation by Bacteria	45
		3.1.3. Losses of Nitrogen	46
		3.1.4. Measurement	47
		3.1.4.1. Depth of Soil Sampling	48
		3.1.4.2. Timing of Sampling	48
		3.1.4.3. Crop Uptake of Nitrate N	49
		3.1.5. Assessment	49
	3.2.	Calibration of Plant-Available N to N Rate	52
	3.2.	3.2.1. Form of N Fertilization	53
		3.2.2. N Fertilizer Efficiency	54 54
	3.3.		34
	5.5.	Cultivar	56
	3.4.	Calibration of Production to N Fertilization	59
	3.4.	3.4.1. Nitrogen Grain Yield Response	60
		3.4.2. Nitrogen Protein Yield Response	69
4.0.	Dhoen	horus Fertility Requirements in Manitoba	80
4.0.	4.1.		80
	4.2.		82
	4.3.	P Uptake by Species and Variety of Cultivar	83
			85
F 0	4.4.	Calibration of Yield Response to P	91
5.0.	5.1.	sium Fertility Requirements in Manitoba Potassium (K) Soil Levels	91
	5.2.		91
			92
	5.3.	K Uptake by Species and Variety of Cultivar Calibration of Yield Response to K	93 94
	5.4.	Calibration of freig kesponse to K	54

TABLE OF CONTENTS (CONTINUATION)

			<u>Page</u>					
6.0.	Sulphur Fertility Requirements in Manitoba							
	6.1.		97					
	6.2.	Calibration of Plant Available S to S Rate	99					
	6.3.	S Uptake by Species and Variety of Cultivar	102					
		Calibration of Yield Response to S	103					
7.0.		nutrient Fertility Requirements in Manitoba	108					
		Micronutrient Reserves	108					
	7.2.	Calibrator of Micronutrient Availability to						
		Fertilization Rate	108					
		7.2.1. Copper	109					
		7.2.2. Zinc	110					
		7.2.3. Manganese	111					
		7.2.4. Boron	111					
	7.3.	Micronutrient Uptake by Crop and Variety	112					
		Calibration of Yield Responses to Micronutrients .	112					
8.0.		sment of the Nutrient-Yield Response Information						
			116					
	8.1.	Nitrogen-Yield Calibration	116					
		Ability to Predict N-Yield Responses	133					
		Ability to Predict Yield Responses to Other						
		Nutrients	135					
	8.4.	Research Directions	137					
APPEN			142					
	ENCES		162					

LIST OF TABLES

<u>Page</u>			
4	Plant Nutrient Content in Alfalfa and Range Found in Plants	Table 1 -	Т
10-11	A Nitrogen Balance for Productive Cropping Systems (A Hypothetical System, Averaged from Numerous Studies Using Tracer ¹⁵ N: These Values are an Approximate Guide for "Average" Soils)	ľable 2 -	Τ
12	Average Nitrate-Nitrogen Levels in Stubble Field Soils in Manitoba and in Individual Manitoba Agriculture Regions of Manitoba (1979-80 to 1986-87)	Table 3 -	r
13	Average Nitrate-Nitrogen Levels in Fallow Field Soils in Manitoba and in Individual Manitoba Agriculture Regions of Manitoba (1979-80 to 1986-87)	Table 4 -	Γ
17	- Average NaHCO3 Extractable Phosphorus Levels in Field Soils in Manitoba and in Individual Manitoba Agriculture Regions of Manitoba (1979-80 to 1986-87)	Table 5 -	T
18	- Average NH4AC Extractable Potassium Levels in Field Soils in Manitoba and in Individual Manitoba Agriculture Regions of Manitoba (1979-80 to 1986-87)	Table 6 -	ני
	Percent of Fields Tested by the Manitoba Soil Testing Laboratory in Various Sulphur Availability Categories (Province Wide)	Tabl e 7 -	ני
•	Percent of Fields Tested by the Manitoba Soil Testing Laboratory in Various Sulphur Availability Categories (Southwest Region)	Table 8 -	J
	Percent of Fields Tested by the Manitoba Soil Testing Laboratory in Various Sulphur Availability Categories (Northwest Region)	Table 9 -	7
	Percent of Fields Tested by the Manitoba Soil Testing Laboratory in Various Sulphur Availability Categories (Central Region)	Table 10 -	7
	- Percent of Fields Tested by the Manitoba Soil Testing Iaboratory in Various Sulphur Availability Categories (Interlake Region)	Table ll -	-
	- Percent of Fields Tested by the Manitoba Soil Testing Laboratory in Various Sulphur Availability Categories (Eastern Region)	Table 12 -	

LIST OF TABLES (CONTINUATION)

				<u>Page</u>
Table	13	-	DTPA Extractable Zinc and Copper Levels in Selected Field Soils in Manitoba	30
Table	14	_	Farm Soil Sample Submissions to the Manitoba Provincial Soil Testing Laboratory (1979-80 to 1986-87)	33
Table	15	-	Percent of Farm Samples Submitted from the Five Manitoba Agriculture Regions (1979-80 to 1986-87)	34
Table	16	-		63
Table	17	-	Recommended Fertilization Rates for Manitoba Field Crops Under General Fertility Conditions (lbs/ac), 1986	66
Table	18	-	Estimated Winter Wheat Yields Based on Stored Soil Water and Seasonal Rainfall Under Average Growing Conditions With Some Problems Such as Weeds, Disease, Fertility, High Temperature or Wind	67
Table	19	-	Estimated Winter Wheat Yields Based on Stored Soil Water and Seasonal Rainfall Under Favorable Growing Conditions With No Problems Such as Weeds, Disease, Fertility, High Temperature or Wind	70
Table	20	_	Available Water Capacities for Soil Textural Classes per 30cm Depths	71
Table	21	-	Relationship Between Nitrogen Protein Content Yield and Water Availability in HRS Wheat Production	74
Table	22	-	Nitrogen Fertilizer Required, kg N/ha (lb N/acre), "Target" Protein Content (%)	76
Table	23	-	Range of P-K-S Nutrient Recommendations for Manitoba Soils, 1986, Without Soil Tests	86
Table	24	-	Comparison of Phosphorus Recommendation for Wheat for Provinces Using the NaHCO ₃ Extractable P as a Soil Test	87
Table	25	-	Percentage Distribution of Phosphorus Soil Test Results in Manitoba	88
Table	26	-	Expected Yield responses to Applied Phosphate, All Soils, Saskatchewan	90

LIST OF TABLES (CONTINUATION)

<u>Page</u>		
ons for	able 27 - Potassium Soil Test Ratings for Various Canadian Provinces, and corresponding Recommendations for Rate of Potassium (K ₂ O) Fertilizers for Wheat	Ta
	able 28 - Rates of Fertilizer S Recommended for Various Cro in the Prairie Provinces	Та
	able 29 - Sulfur Soil test Methods Used by Provincial Laboratories in Western Canada	Та
es in	able 30 - Criteria Used in Interpretation of Micronutrient Soil Tests in Provincial Soils Laboratories in Western Canada	Ta
n Prairie	Pable 31 - Recommended Rates for Copper, Manganese and Zinc Fertilization of Wheat in Western Canadian Prairies Soils	Ta
	Pable 32 - Average N Fertilization of Stubble Wheat, Manitol 1981 to 1985 by MCIC Soil Class, N Rate (lbs/ac)	Ta
	Pable 33 - Average P Fertilization of Stubble Wheat, Manitol 1981 to 1985 by MCIC Soil Class, P Rate (lbs/ac)	Ta
l Testing t Region —	Pable 34 - Comparison of Actual Yields with Target Yields Based on N-Rates, Manitoba Provincial Soil Testin Laboratory, Stubble Wheat, 1985, Southwest Region "Dry" Moisture Index	Ta
l Testing t Region -	Pable 35 - Comparison of Actual Yields with Target Yields Based on N-Rates, Manitoba Provincial Soil Testil Laboratory, Stubble Wheat, 1985, Northwest Region "Moist" Moisture Index	Τā
l Testing	Pable 36 - Comparison of Actual Yields with Target Yields Based on N-Rates, Manitoba Provincial Soil Testi Laboratory, Stubble Wheat, 1985, Central Region "Moist" Moisture Index	Tā
l Testing	Table 37 - Comparison of Actual Yields with Target Yields Based on N-Rates, Manitoba Provincial Soil Testi Iaboratory, Stubble Wheat, 1985, Interlake Regio "Moist" Moisture Index	T
l Testing	Table 38 - Comparison of Actual Yields with Target Yields Based on N-Rates, Manitoba Provincial Soil Testi Laboratory, Stubble Wheat, 1985, Eastern Region "Moist" Moisture Index	T

LIST OF TABLES (CONTINUATION)

		Page
Table 39 - Region:	Southwest 1981 to 1985	128
Table 40 - Region:	Northwest 1981 to 1985	129
Table 41 - Region:	Central 1981 to 1985	130
Table 42 - Region:	Interlake 1981 to 1985	131
Table 43 - Region:	Eastern 1981 to 1985	132
Table 44 - Yield Va	riability - Barley 1962 to 1968	140

LIST OF FIGURES

				Page
Figure 1	1 .	-	Canada-Manitoba Crop Insurance Risk Areas and Crop Insurance Regions of Manitoba	14
Figure 2	2		Characteristic Shape of the Relationship of Growth Response to Increasing N Supply (Reproduced from Tucker, 1984, p. 215)	43
Figure :	3	-	Relationship Between N Uptake and N Levels for Barley, Manitoba (From Fehr, 1970)	50
Figure	4	-	Soil Water Deficit on August 13	64
Figure	5	_	Ideal Growing Conditions, N Requirement = 4.2 kg/100 kg	72
Figure	6	-	Growing Condition Problems	73
Figure	7	_	Crop Variety Zone Map for Manitoba	77
Figure	8	-	Plant Nutrient Requirements of Oilseed and Pulse Crops	78
Figure	9	-	Canada-Manitoba Crop Insurance Risk Areas and Crop Insurance Regions of Manitoba	118
Figure	10	_	Variance of Barley Yields About Expected Yield	139

REFERENCES

- 1. Alberta Soil Science Workshop. <u>Proceedings of Western Canada Nitrogen Symposium</u>, Edmonton, January 21-21, 1976.
- 2. Alberta Soil Science Workshop. <u>Proceedings of the Western</u> <u>Canada Phosphate Symposium</u>, Calgary, March 11-12, 1980.
- 3. Anderson, D.W. "Available Sulphur in Some Manitoba Soils as Estimated by Plant Growth and Chemical Analysis." M.Sc. Thesis, University of Manitoba, Winnipeg, 1966.
- 4. Arnon, D.L. and P.R. Stout. "The Essentiality of Certain Elements in Minute Quantity for Plants with Special Reference to Copper." Plant Physical 14(1939):371-5.
- 5. Bailey, L.D. "The Paradox of NO₃ in the Soil Environment." <u>Proceedings of the 15th Annual Manitoba Soil Science Meeting</u>, Winnipeg, December 8-9, 1971.
- 6. Bailey, L.D. "Nutrient Requirements of Fababeans." <u>Proceedings</u> of the 20th Annual Manitoba Soil Science Meeting, Winnipeg, 1976, pp. 140-43.
- 7. Bailey, L.D. "Nutrient Requirements of Soybeans." <u>Proceedings</u> of the 21st Annual Manitoba Soil Science Meeting, Winnipeg, 1977, pp. 196-199.
- 8. Bailey, L.D. "Sulphur Status of Some Western Manitoba Soils." Proceedings of the 22nd Annual Manitoba Soil Science Meeting, Winnipeg, 1978, pp. 101-9.
- 9. Bailey, L.D. "The Effect of N-Serve Nitrogen Stabilizer and Nitrogen Fertilizers on the Yield and Nitrogen Composition of Barley and Rapeseed." <u>Proceedings of the 25th Annual Manitoba Soil Science Meeting</u>, Winnipeg, January 11-12, 1982.
- 10. Bailey, L.D. "The Sulphur Status of Eastern Canadian Prairie Soils: The Relationship of Sulphur, Nitrogen and Organic Carbon." <u>Canadian Journal of Soil Science</u>, 65(1985):179-86.
- 11. Bailey, L.D. "The Sulphur Status of Fastern Canadian Prairie Soils: Sulphur Response and Requirements of Alfalfa (Medicago satwa L.), Rape (Brassica napus L.) and Barley (Hordeum vulgare L.)." Canadian Journal of Soil Science, 66(1986):209-16.
- 12. Bailey, L.D. "Sulfur Status of Manitoba Soils: Relationship to SO_4^{-2} Availability and Plant Growth." <u>Proceedings of 30th Annual Manitoba Society of Soil Science Meeting</u>, Winnipeg, January 6-7, 1987, pp. 72-78.

- 13. Bailey, L.D., E.D. Spratt, D.W.L. Read, F.G. Warder and W.S. Ferguson. "Residual Effects of Phosphorus Fertilizer II. For Wheat and Flax Grown on Chernozemic Soils in Manitoba." Canadian Journal of Soil Science 57(1977):263-70.
- 14. Bailey, L.D., E.D. Spratt, D.W.L. Read, F.G. Warder and W.S. Ferguson. "Effect of Phosphorus Placement on Crop Uptake and Yield." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, p. 200-229.
- 15. Barber, S.A. "A Diffusion and Mass-Flow Concept of Soil Nutrient Availability." <u>Canadian Journal of Soil Science</u> 93(1962):39-49.
- 16. Barber, S.A. "Nutrient Balance and Nitrogen Use." Hauck, R.D. (Editor) Nitrogen in Crop Production. American Society of Agronomy, Madison, Wisconsin (1984):87-96.
- 17. Beaton, J.D. "The Role of NPKS." <u>Proceedings of Prairie Production Symposium</u>, Advisory Committee to the Canadian Wheat Board. Session IV, Saskatoon, Saskatchewan, 1980.
- 18. Beaton, J.D., J.T. Haradiak and S.L. Tisdale. "Crop Responses to Sulphur in Western Canada." <u>Sulphur Institute Journal</u> 2(3, 1966):9-16.
- 19. Beaton, J.D. and R.J. Soper. "Plant Response to Sulfur in Western Canada." Tabatabai, M.A. (Editor) Sulfur in Agriculture. American Society of Agronomy, Inc., Madison, Wisconsin (1986):375-403.
- 20. Bettany, J.R., S. Saggar and J.W.B. Stewart. "Comparison of the Amounts and Forms of Sulphur in Organic Matter Fractions After 65 Years of Cultivation." Soil Science Society of America Journal 44(1980):70-75.
- 21. Biederbeck, V.O., C.A. Campbell and R.P. Zentner. "Effect of Crop Rotation and Fertilization on Some Biological Properties of a Loam in Southwestern Saskatchewan." <u>Canadian Journal of Soil Science</u> 64(1984):355-67.
- 22. Blair, G.J., C.P. Mamaril and M.H. Miller. "Influence of Nitrogen Source on Phosphorus Uptake by Corn From Soils Differing in pH." Agronomy Journal 63(1971):235-8.
- 23. Brady, N.C. "The Nature and Properties of Soils." 9th Edition. New York: Collier MacMillan Publishers, 1984.
- 24. Breakey, G. "Summary of Spring and Fall Soil Sampling." <u>Proceedings of 10th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1966, pp. 13-17.

- 25. Brown, P.L. and A.L. Black. "Stubble Seeding and Fertilization of Winter Wheat." Fowler, D.B., L.V. Gusta, A.E. Slinkard and B.A. Hobin (Editors). Proceedings of the Western Canada Winter Wheat Conference, University of Saskatchewan, Saskatoon, June 20-22, 1983.
- 26. Bushuk, W., F.J. Rodriques-Bores and S. Dubetz. "Effects of High Rates of Nitrogen on Neepawa Wheat Grown Under Irrigation III Protein Quality for Breadmaking as Reflected by Various Tests." <u>Canadian Journal of Plant Science</u> 58(1978):923-7.
- 27. Campbell, C.A. "Positive Changes in Organic Matter with Zero-Till." <u>Proceedings of 5th Annual Manitoba-North Dakota Zero</u> <u>Tillage Workshop</u>, Brandon, Manitoba, January 20-21, 1983.
- 28. Campbell, C.A., R. de Jong and R.P. Zentner. "Effect of Cropping, Summerfallow and Fertilizer Nitrogen on Nitrate-Nitrogen Lost by Leaching on a Brown Chernozemic Loam." Canadian Journal of Soil Science 64(1984):61-74.
- 29. Campbell, C.A., R.P. Zentner, J.F. Dormaar and R.P. Voroney. "Land Quality, Trends and Wheat Production in Western Canada." Slinkard and Fowler (Editors). "Wheat Production in Canada A Review." Proceedings of the Canadian Wheat Production Symposium, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, (March 3-5, 1986):318-53.
- 30. Christianson, C.B., R.A. Hedlin and C.M. Cho. "Loss of Nitrogen From Soil During Nitrification of Urea." <u>Canadian Journal of Soil Science</u> 59(1979):147-54.
- 31. Clayton, J.S., W.A. Ehrlich, D.B. Cann, J.H. Day and I.B. Marshall. "Soils of Canada." Ottawa: Canada Department of Agriculture, Research Branch, 1977.
- 32. Cook, F.D., F.C. Warder and J.L. Doughty. "The Relationship of Nitrate Accumulation to Yield Response of Wheat in Some Saskatchewan Soils." <u>Canadian Journal of Soil Science</u> 37(1956):84-8.
- 33. de Jong, E. and D.A. Rennie. "Physical Soil Factors Influencing the Growth of Wheat." Nielson, K.E. (Editor). <u>Proceedings of the Canadian Centennial Wheat Symposium</u>, Modern Press, Saskatoon, 1967, pp.69-132.
- 34. Donahue, R.L., R.W. Miller and J.C. Shickluna. "Soils: An Introduction to Soils and Plant Growth." 5th Edition. Englewood Cliffs, N.J.: Prentice-Hall Inc. (1983).

- 35. Drysdale, R.A. "Investigations of the Severity, Extent, Type and Treatment of Copper Deficiency in Beef Cattle in Northwestern Manitoba." M.Sc. Thesis, University of Manitoba, Winnipeg, 1979.
- 36. Dubetz, S. "Effects of Nitrogen on Yield and Protein Content of Manitoba and Pitic Wheats Grown Under Irrigation." <u>Canadian Journal of Plant Science</u> 52(1972):887-90.
- 37. Dubetz, S. "Effects of High Rates of Nitrogen on Neepawa Wheat Grown Under Irrigation I Yield and Protein Content." <u>Canadian Journal of Plant Science</u> 57(1977):331-6.
- 38. Dubetz, S. E.F. Gardiner, D. Flynn and A.I. de la Roche.
 "Effect of Nitrogen Fertilizer on Nitrogen Fractions and Amino Acid Composition of Spring Wheat." <u>Canadian Journal of Plant Science</u> 59(1979):299-305.
- 39. Eagle, D.J. and B.C. Matthews. "Measurement of Nitrate-Supplying Power of Soils by an Incubation Method and Correlation with Crop Yield." <u>Canadian Journal of Soil Science</u> 38(1958):161-70.
- 40. Fehr, P. "Interpretation of Target Yield Fertilizer Recommendations." <u>Proceedings of the 14th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1970, pp. 79-90.
- 41. Fehr, P. "Comparison of Actual Farm Yields and Target Yields-1972 Crop." <u>Proceedings of the 17th Annual Manitoba Soil</u> <u>Science Meeting</u>, Winnipeg, 1973, pp. 137-141.
- 42. Feyerherm, A.M. and G.M. Paulsen. "Development of a Weather-Yield Function for Winter Wheat." <u>Agronomy Journal</u> 78(1986):1012-17.
- 43. Freyman, S., C.J. Palmer, E.H. Hobbs, J.F. Dormaar, G.B. Schaalje and J.R. Moyer. "Yield Trends on Long-Term Dryland Wheat Rotations at Lethbridge." <u>Canadian Journal of Plant Science</u> 62(1982):609-19.
- 44. Gehl, D.T., J.M. Sadler and R.B. Irvine. "Nitrogen Requirements of Semi-Dwarf Versus Conventional Varieties of Wheat Under Manitoba Conditions." <u>Proceedings of the 29th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1986, pp. 73-90.
- 45. Gehl, D.T., J.M. Sadler and R.B. Irvine. "Nitrogen Fertility Responses of Standard Height and Semi-Dwarf Barley Cultivars Under Manitoba Conditions." <u>Proceedings of the 30th Annual Manitoba Society Science Meeting</u>, Winnipeg, 1987, pp. 209-213.

- 46. Gehl, D.T. and J.M. Sadler. "Nitrogen Requirements of Spring Wheats Do the Semi-Dwarfs Need More?" <u>Proceedings of the Manitoba Agronomists' Conference</u>, Winnipeg, 1987, pp. 45-8.
- 47. Gorby, B.J. "Fertilizers for Fall Rye, 1968-9." <u>Proceedings of the 13th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1960, pp.182-4.
- 48. Grant, C.A. "Nitrogen and Phosphorus Fertilization in the Prodcition of Winter Wheat Under Zero Tillage Management." M.Sc. Thesis. Winnipeg, (1982).
- 49. Grant, C.A. and G.J. Racz. "Calcium-Magnesium-Potassium Interactions in High Mg Systems." <u>Proceedings of 29th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1986, pp. 87-106.
- 50. Grant, C.A. and G.J. Racz. "The Effect of Ca and Mg Concentrations in Nutrient Solution on the Dry Matter Yield and Ca, Mg, and K Content of Barley (Hordeum vulgare L.)." <u>Canadian</u> Journal of Soil Science 67(1987):857-66.
- 51. Green, B.J. and A.O. Ridley. "Effect of Nitrogen Supply on Yield and Protein Content of Winter Wheat Under Zero Tillage and Spring Wheat Under Zero and Conventional Tillage." <u>Proceedings of 29th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1986, pp. 136-143.
- 52. Hagborg, W.A.F. "Gray Speck of Oats in Western Canada." Canadian Plant Dis. Survey 53(1973:72-8.
- 53. Hagstrom, G.R. "Fertilizer Sources of Sulphur and Their Use."
 Tabatabai, M.A. (Editor). "Sulfur in Agriculture." American
 Society of Agronomy, Madison, Wisconsin 27(1986):567-582.
- 54. Hamm, J.W. "Sulfur on Rapeseed and Cereals." <u>Proceedings of 10th Annual Manitoba Soil Science Meeting</u>, University of Manitoba, Winnipeg, 1967, pp. 91-5.
- 55. Harapiak, J.T., R.M.N. Kucey and D. Flaten. "Nitrogen Sources and Placement in Wheat Production." Slinkard, A.E. and D.B. Fowler (Editors). Wheat Production in Canada: A Review. Proceedings of Canadian Wheat Symposium, University of Saskatchewan, Saskatoon, 1986, pp. 87-135.
- 56. Hauck, R.D. (Editor). "Nitrogen in Crop Production." <u>Proceedings of a Symposium at Sheffield</u>, Alabama, May 25-27, 1982. American Society of Agronomy, Madison, Wisconsin, 1984.
- 57. Hedayat, M.M. "The Effect of Zinc Rate and Method of Placement on Yield and Zinc Utilization of Black Beans." (<u>Phasealus vulgaris</u> var. Black Turtle) and fababeans (<u>Vicia faba</u> L. var. Minor). M.Sc. Thesis, University of Manitoba, Winnipeg, 1978.

- 58. Henry, L. "Soil Available Phosphorus in Relation to Soil Classification." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp. 256-275.
- 59. Henry, J.L., J.B. Bole and R.C. McKenzie. "Effect of Nitrogen Water Interactions on Yield and Quality of Wheat in Western Canada." Slinkard and Fowler (Editors). "Wheat Production in Canada A Review." Proceedings of the Canadian Wheat Production Symposium, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, (March 3-5, 1986):165-191.
- 60. Hnatowich, G.L., L. Loewen-Rudgers and R.J. Soper. "Fertility Studies of Special Crops." <u>Proceedings of the 26th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1982, pp. 145-153.
- 61. Jackson, T.L., D.T. Westermann and D.P. Moore. "The Effect of Chloride and Lime on the Manganese Uptake by Bush Beans and Sweet Corn." Soil Science Society of America Journal 30(1966):70.
- 62. Janzen, H.H. and J.R. Bettany. "Sulfur Nutrition of Rapeseed:
 1. Influence of Fertilizer Nitrogen and Sulfur Rates." Soil
 Science Society of America Journal 48(1984):100-7.
- 63. Janzen, H.H. and J.R. Bettany. "Oxidation of Elemental Sulphur Under Field Conditions in Central Saskatchewan." <u>Canadian Journal of Soil Science</u> 67(1987):609-18.
- 64. Janzen, H.H. "Effect of Fertilizer on Soil Productivity in Long Term Spring Wheat Rotations." <u>Canadian Journal of Soil Science</u> 67(1987):165-74.
- 65. Jones, M.B. "Sulfur Availability Indexes." Tabatabai, M.A. (Editor). Sulfur in Agriculture. American Society of Agronomy, Madison, Wisconsin 27(1986):549-566.
- 66. Josephson, R. and D.M. Zbeetnoff. "Information Needs in Choosing Fertilizer Rates." Extension Report, 1988. Department of Agricultural Economics and Farm Management, University of Manitoba, Winnipeg.
- 67. Karamanos, R.E., G.A. Kruger and J.P. Singh. "The Micro-Nutrient Status of Saskatchewan Soils." <u>Proceedings of 27th</u> <u>Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1984, pp. 154-172.
- 68. Karamanos, R.E., G.A. Kruger and J.W.B. Stewart. "Copper Deficiency in Cereal and Oilseed Crops in Northern Canadian Prairie Soils." <u>Agronomy Journal</u> 78(1986):317-23.

- 69. Kowalenko, C.G., E.F. Maas and C.I. Vanlaerhoven. "Residual Effects of High Rates of Limestone, P, K and Mg Applications: Evidenced of Induced Mn and Zn Deficiency in Oats." <u>Canadian Journal of Soil Science</u> 60(1980):757-61.
- 70. Kruger, G.A., R.E. Karamanos and J.P. Singh. "The Copper Fertility of Saskatchewan Soils." <u>Canadian Journal of Soil Science</u> 65(1985):89-99.
- 71. Kucey, R.M.N. "Effect of Fertilizer Farm, Method and Timing of Application on Barley Yield and N Uptake Under Dryland Conditions in Southern Alberta." <u>Canadian Journal of Soil Science</u> 68(1986):615-21.
- 72. Leitch, R.H., K.S. McGill and H. Chauh. "Soil Test Methods and Trends in Phosphorus Status of Western Canadian Soils." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp. 24-64.
- 73. Leyshon, A.J. C.A. Campbell and F.G. Warder. "Comparison of the Effect of NO₃ and NH₄[†]N on Growth, Yield and Yield Components of Manitoba Spring Wheat and Conquest Barley." <u>Canadian Journal of Plant Science</u> 60(1980):1063-70.
- 74. Loewen-Rudgers, L., D. McAndrew and D. McKenzie. "Micro-Nutrient Deficiencies in Manitoba Crops." <u>Proceedings of 22nd Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1978, pp. 114-119.
- 75. Loewen-Rudgers, L.A., K. McGill, G.J. Racz, A.O. Ridley and R.C. Soper. "Soil Fertility and Fertilizer Practices." <u>Principles and Practices of Commercial Farming</u>, Faculty of Agriculture, University of Manitoba, Winnipeg, 1977.
- 76. Malhi, S.S. "Overwinter Mineralization of Soil Nitrogen."
 Unpublished Results, Department of Soil Science, University of
 Manitoba. Cited from Nyborg, M., J. Neufeld and R.A. Bertrand.
 "Measuring Crop Available Nitrogen." Alberta Soil Science
 Workshop. Proceedings of Western Canada Nitrogen Symposium,
 Calgary, 1976, pp. 102-27.
- 77. Malhi, S.S. and M. Nyborg. "Rate of Hydrolysis of Urea as Influenced by the Thiourea and Pellet Size." Plant Soil 51(1979):177-86.
- 78. Manitoba. "Soil Testing Services in Manitoba." Department of Agriculture, Winnipeg. Agdex 533 (1983(a)).
- 79. Manitoba. "Phosphorus Application for Annual Crops."
 Department of Agriculture, Winnipeg. Agdex 541 (1983(b)).

- 80. Manitoba. "Micronutrients in Crop Production." Department of Agriculture, Winnipeg. Agdex 541 (November, 1985).
- 81. Manitoba. "Soil Facts: Nitrogen Fertilization in Crop Production." Department of Agriculture, Winnipeg. Agdex 540 (1986a).
- 82. Manitoba. "Field Crop Variety Recommendations for Manitoba." Department of Agriculture, Winnipeg, 1986b.
- 83. Manitoba. "Field Crop Variety Recommendations for Manitoba." Department of Agriculture, University of Manitoba, Winnipeg, 1987.
- 84. Manitoba Provincial Soil Testing Laboratory. Target Yield Tables. Department of Soil Science, University of Manitoba, Winnipeg, September 1982.
- 85. Manitoba. "Nutrient Recommendation Guidelines." Soil Fertility Advisory Committee, Winnipeg, September 15, 1982.
- 86. Martens, J.W., R.I.H. McKenzie and V.M. Bendelow. "Manganese Levels of Cats in Western Canada." <u>Canadian Journal of Plant Science</u> 57(1977):383-7.
- 87. Maynard, D.G., J.W.B. Stewart and J.R. Bettany. "Use of Plant Analysis to Predict Sulphur Deficiency in Rapeseed (Brassica napus and B. campestris)." <u>Canadian Journal of Soil Science</u> 63(1983):387-96.
- 88. McAndrew, D.W. "Copper and Zinc Nutrition of Cereal and Oilseed Crops in Manitoba." M.Sc. Thesis, University of Manitoba, Winnipeg, 1979.
- 89. McCready, R.G.L. and H.R. Krouse. "Sulphur Isotope Fractionation During the Oxidation of Elemental Sulfur by Thiobacilli in a Solonetzic Soil." <u>Canadian Journal of Soil Science</u> 62(1982):105-10.
- 90. McGregor, W.R. "A Study of the Copper and Zinc Status of Some Manitoba Soils." M.Sc. Thesis, University of Manitoba, Winnipeg, 1972.
- 91. McGill, K.S. "Fertility Status of Manitoba Soils Following the 1980 Drought." Proceedings of Manitoba Agronomists Conference, Winnipeg, 1980, pp. 110-26.
- 92. McGill, K.S. "Climate Mcdified Fertilizer Recommendations for Wheat, Barley and Oats." <u>Proceedings of Manitoba Agronomists Conference</u>, Winnipeg, 1982, pp. 137-9.

- 93. McGill, K.S. "Nutrient Trends in Manitoba Soils: A Summary of Results From the Provincial Soil Testing Laboratory."

 <u>Proceedings of 30th Annual Manitoba Soil Science Meeting</u>,
 Winnipeg, 1987, pp. 172-85.
- 94. Meisinger, J.J. "Evaluating Plant-Available Nitrogen in Soil-Crop Systems." Hauck, R.D. (Editor). "Nitrogen in Crop Production." Proceedings of a Symposium at Sheffield, Alabama, May 25-27, 1982. American Society of Agronomy, Madison, Wisconsin, 1984, pp. 391-416.
- 95. Miller, M.H., C.P. Mamaril and G.J. Blair. "Ammonium Effects on Phosphorus Absorption Through pH Changes and Phosphorus Precipitation at the Soil-Root Interface." <u>Agronomy Journal</u> 62(1970):524-7.
- 96. Nielson, K.F. (Editor). <u>Proceedings of the Canadian Centennial</u> <u>Wheat Symposium</u>, Saskatoon, Modern Press, 1967.
- 97. Nuttal, W.F., H.G. Zandstra and K.E. Bowren. "Exchangeable Ammonium and Nitrate-Nitrogen Related to Yields of Conquest Barley Grown as Second or Third Crop After Fallow in Northeastern Saskatchewan." <u>Canadian Journal of Soil Science</u>, 51(1971):371-7.
- 98. Nuttal, W.F., H. Ukrainetz, J.W.B. Stewart and D.T. Spurr. "The Effect of Nitrogen, Sulphur and Boron on Yield and Quality of Rapeseed (Brossica napus L. and B. campestris L.)." <u>Canadian Journal of Soil Science</u> 67(1987):545-60.
- 99. Nyborg, M. "Sulfur Deficiency in Cereal Grains." <u>Canadian</u> Journal of Soil Science, 48(1968):37-41.
- 100. Nyborg, M. and C.F. Bentley. "Sulphur Deficiency in Rapeseed and Cereal Grains." <u>Sulphur Institute Journal</u> 7(3, 1971):16-17.
- 101. Nyborg, M. and P.B. Hoyt. "Boron Deficiency in Turnip Rape Grown on Grey-Wooded Soils." <u>Canadian Journal of Soil Science</u> 50(1970):87-88.
- 102. Nyborg, M. and S.S. Machi. "Increasing the Efficiency of Fall-Applied Urea Fertilizer by Placing in Big Pellets or in Nests." Plant Soil 52(1979):461-5.
- 103. Nyborg, M., J.A. Neufeld and R.A. Bertrand. "Measuring Crop Available Nitrogen." Alberta Soil Science Workshop.

 Proceedings of Western Canada Nitrogen Symposium, Edmonton, 1976, pp. 102-127.

- 104. Nyborg, M., et al. "Use of Soil Tests to Predict Nitrogen Fertilizer Needs of Barley and Rapeseed in Alberta."

 <u>Proceedings of the Saskatchewan Soil Fertility Workshop</u>, The Extension Division, University of Saskatchewan, 1974, pp. 74-82.
- 105. Olomu, M.O. and G.J. Racz. "Effect of Soil Water and Aeration on Fe and Mn Utilization by Flax." Agronomy Journal 66(1974):523-6.
- 106. Penney, D.C. and J.L. Henry. "Reaction of Fertilizer Nitrogen with Soil Components." Alberta Soil Science Workshop. Proceedings of Western Canada Nitrogen Symposium, Edmonton, 1976, pp. 274-98.
- 107. Peterson, G.A. and R.D. Voss. "Management of Nitrogen in the West North Central States." Hauck, R.D. (Editor). "Nitrogen in Crop Production." Proceedings of a Symposium at Sheffield, Alabama, May 25-27, 1982. American Society of Agronomy, Madison, Wisconsin, 1984, pp. 721-734.
- 108. Porter, M.A., S.M. Paulsen, A.M. Feyerherm and F.M. Milliken. "Prediction of Wheat Grain Protein Content From Climatic and Edaphic Variables." Agronomy Journal 74(1982):1029-31.
- 109. Racz, G.J. "Effect of Fertilizers on Corn and Sunflowers."

 Proceedings of the 11th Annual Manitoba Soil Science Meeting,
 Winnipeg, 1967, pp. 238-41.
- 110. Racz, G.J. "Effect of Fertilizers on Corn and Sunflowers."

 Proceedings of the 13th Annual Manitoba Soil Science Meeting,
 Winnipeg, 1969(a), pp. 172-6.
- 111. Racz, G.J. "Effect of Fertilizers on Flax 1968." <u>Proceedings</u> of the 13th Annual Manitoba Soil Science Meeting, Winnipeg, 1969(b), pp. 177-9.
- 112. Racz, G.J. "Effect of Fertilizers on Flax 1969." <u>Proceedings of the 14th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1970(a), pp. 136-8.
- 113. Racz, G.J. "Effects of Fertilizers on Peas." <u>Proceedings of the 14th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1970(b), pp. 142-5.
- 114. Racz, G.J. "Effect of Fertilizers on Corn and Sunflowers-1969." <u>Proceedings of the 14th Annual Manitoba Soil Science</u> <u>Meeting</u>, Winnipeg, 1970(c), pp. 146-153.
- 115. Racz, G.J. "Effect of Fertilizers on Buckwheat." <u>Proceedings</u> of the 15th Annual Manitoba Soil Science Meeting, Winnipeg, 1971, pp. 156-8.

- 116. Racz, G.J. "Effect of Nitrogen Supply, Water Supply and Temperature on the Yield and Protein Content of Cereal Grains."

 Proceedings of 18th Annual Manitoba Soil Science Meeting, Winnipeg, 1974, pp. 219-28.
- 117. Racz, G.J. "Effect of Depth of Sampling on the Relationship Between Nitrogen Uptake and Amount of NO₃ N in the Soil." Proceedings of the 23rd Annual Manitoba Soil Science Meeting, Winnipeg, 1979(a), pp. 121-29.
- 118. Racz, G.J. "Losses of Fertilizer Nitrogen as Affected by Time and Method of Application Manitoba." <u>Proceedings of the Annual Alberta Soil Science Workshop Meeting</u>, Lethbridge, February 26-27, 1979(b).
- 119. Racz, G.J. "Method and Time of Phosphorus Application for Annual Crops." Proceedings of the 24th Annual Manitoba Soil Science Meeting, Winnipeg, 1980, pp. 115-130.
- 120. Racz, G.J. "Effects of Agronomic Practices on Protein Content of Wheat." Paper presented at the Wheat Protein Management Workshop, Canadian International Grains Institute, Winnipeg, February 17-18, 1983.
- 121. Racz, G.J. and P. Haluschak. "Effect of Phosphorus Levels on the Cu, Zn, Fe and Mn Utilization by Wheat and Flax."

 Proceedings of the 14th Annual Manitoba Soil Science Meeting, Winnipeg, 1970, pp. 79-90
- 122. Racz, G.J. M.D. Webber, R.J. Soper and R.A. Hedlin. "Phosphorus and Nitrogen Utilization by Rape, Flax and Wheat." Agronomy Journal 57: (1965):335-7.
- 123. Read, D.W.l., E.D. Spratt, L.D. Bailey and F.G. Warder. "Residual effects of Phosphorus Fertilizer I. For Wheat Grown on Four Chernozemic Soil Types in Saskatchewan and Manitoba." Canadian Journal of Soil Science 57(1977):255-62.
- 124. Reid, J.M. and G.J. Racz. "Effect of Cu, Mn and B Fertilization on Yield and Chemical Composition of WHeat and Barley."

 Proceedings of the 24th Annual Manitoba Soil Science Meeting, Winnipeg, 1980, pp. 107-114.
- 125. Rennie, D.A. "Organic Matter-Fertility Loss in Saskatchewan."

 Proceedings of Saskatchewan Federation of Agriculture Workshop
 on 'Saskatchewan Soils, a Fragile Resource', Regina, 1983.
- 126. Ridley, A.O. "Effect of Nitrogen and Sulfur Fertilizer on Yield and Quality of Rapeseed." <u>Proceedings of the 16th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1972, pp. 149-55.

- 127. Ridley, A.O. "Effect of Nitrogen and Sulfur Fertilizers on Yield and Quality of Rapeseed." <u>Proceedings of the 17th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1973, pp. 182-7.
- 128. Ridley, A.D. 'Nitrogen Fertilizers, Time and Method of Placement." <u>Proceedings of the 21st Annual Manitoba Soil Science Meeting</u>, Winnipeg, December 7-8, 1977.
- 129. Robertson, J.A. "Use of P. Sorption Parameters to Predict Fertilizer-P Requirements." Alberta Soil Science Workshop.

 <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp. 91-121.
- 130. Rogalsky, J.R. "Fertilizer Response of Silage Corn."

 Proceedings of the 13th Annual Manitoba Soil Science Meeting,
 Winnipeg, 1969, pp. 180-1.
- 131. Rogalsky, J.R. "Summary of Fababeans Fertility Trials." Proceedings of the 16th Annual Manitoba Soil Science Meeting, Winnipeg, 1972, pp. 169-70.
- 132. Russell, E.W. "Soil Conditions and Plant Growth." 10th Edition. London: Longman Group Ltd., 1973.
- 133. Sadler, J.M. and P.E. Fehr. "A Survey of the Macro- and Micro-Element Nutritional Status of Corn Growing on Manitoba Soils." <u>Proceedings of the 19th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1975, pp. 141-6.
- 134. Sadler, J.M. "Sorghum N, P and K Fertility Studies." Proceedings of the 26th Annual Manitoba Soil Science Meeting, Winnipeg, 1983, pp. 114-7.
- 135. Saskatchewan. "Fertilizer Economics." Economics Branch, Farm Management Section, Department of Agriculture, March, 1986.
- 136. Shaykewich, C.F. "Climate of Southern Manitoba as It Relates to Agriculture." Manitoba Department of Agriculture, Winnipeg, Publication #546, 1974.
- 137. Shaykewich, C.F., L. Martin, G. Thompson, A. MacMillan and E.H. Stobbe. "Soil Factors Affecting Efficacy of Soil Applied Herbicides." Proceedings of the 18th Annual Manitoba Soil Science Meeting, Winnipeg, 1974, pp. 76-82.
- 138. Sheppard, S.C. and G.J. Racz. "Phosphorus Nutrition of Crops as Affected by Temperature and Water Supply." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp. 159-199.

- 139. Singh, J.P., R.E. Karamanos and J.W.B. Stewart. "P-Induced Zn Deficiency in Wheat on Residual P Plots." <u>Agronomy Journal</u> 78(1986):668-75.
- 140. Singh, J.P., R.E. Karamanos and J.W.B. Stewart. "The Zinc Fertility of Saskatchewan Soils." <u>Canadian Journal of Soil Science</u> 67(1987):103-116.
- 141. Skogley, E.O. and V.A. Haby. "Predicting Crop Responses on High-Potassium Soils at Frigid Temperature and Ustic Moisture Regimes." Soil Science Society of America Journal 45(1981):533-6.
- 142. Slinkard, A.E. and D.B. Fowler. "Wheat Production in Canada A Review." <u>Proceedings of the Canadian Wheat Production Symposium</u>, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, March 3-5, 1986.
- 143. Smid, A.E. and E.D. Spratt. "Yield and Elemental Composition of Corn as Influenced by P, K, Mn, Zn and Cu Fertilizer."

 <u>Proceedings of the 18th Annual Manitoba Soil Science Meeting</u>,
 Winnipeg, 1974, pp. 213-8.
- 144. Smith, R.E. "Molybdenum in Soils, Forage Crops and Water Supply in the Swan River Valley of Manitoba." M.Sc. Thesis, University of Manitoba, Winnipeg, 1955.
- 145. Soper, R.J. "Sulphur Status of Some Manitoba Soils." Proceedings of the 6th Annual Manitoba Soil Science Meeting, Winnipeg, 1963, pp. 75-77.
- 146. Soper, R.J. "Soil Tests as a Means of Predicting Response of Rape to Added N, P and K." <u>Agronomy Journal</u> 63(1971):564-6.
- 147. Soper, R.J. "New Information on the Need for Sulphur in Western Canada." <u>Proceedings of the 14th Annual Meeting of the Western Canada Fertilizer Association</u>, Edmonton, 1978.
- 148. Soper, R.J. and P.M. Huang. "The Effect of Nitrate Nitrogen in the Soil Profile on the Response of Barley to Fertilizer Nitrogen." <u>Canadian Journal of Soil Science</u> 43(1963):350-8.
- 149. Soper, R.J. and G.J. Racz. "Chemical Factors of Soil."

 Nielson, K.F. (Editor). <u>Proceedings of Canadian Centennial</u>

 Wheat Symposium, Saskatoon: Modern Press, 1967, pp. 139-71.
- 150. Soper, R.J. and G.J. Racz. "Fertilizer Management with Low Grain Prices." <u>Proceedings of the 10th Annual Manitoba Weed Fair</u>, Winnipeg, January 20-21, 1987, pp. 19-23.

- 151. Soper, R.J., G.J. Racz and P.J. Fehr. "Nitrate Nitrogen in the Soil as a Means of Predicting the Fertilizer Nitrogen Requirements of Barley." <u>Canadian Journal of Soil Science</u> 51(1971):45-49.
- 152. Spratt, E.D. "The Effect of Soil Factors on Flax Growth, Yield, Nutrient Uptake and Response to Phosphate Fertilizer."

 <u>Proceedings of the 24th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1980, pp. 164-89.
- 153. Spratt, E.D. and B. Andrews. "Nutritional Status of Manitoba Corn, 1973-77." <u>Proceedings of the 22th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1978, pp. 81-97.
- 154. Spratt, E.D. and D.W.L. Read. "Long-Term Benefits of Residual Phosphorus for Small Grains and Forage Crops." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp 122-139.
- 155. Spratt, E.D. and A.E. Smid. "Yield and Elemental Composition of Flax as Affected by P and Micronutrients." Agronomy Journal 70(1978):633-38.
- 156. Stanford, G. and J.O. Legg. "Nitrogen and Yield Potential."
 Hauck, R.D. (Editor). "Nitrogen in Crop Production."
 Proceedings of a Symposium at Sheffield, Alabama, May 25-27,
 1982. American Society of Agronomy, Madison, Wisconsin, 1984,
 pp. 263-272.
- 157. Stepphun, H. and R.P. Zentner. "Water Utilization and Water Use Efficiency in Relation to Yield and Quality of Red Spring Wheat." Slinkard and Fowler (Editors). "Wheat Production in Canada A Review." Proceedings of the Canadian Wheat Production Symposium, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, March 3-5, 1986, pp. 136-164.
- 158. Stewart, J.W.B., M.J. Hedley and B.S. Chauhan. "The Immobilization, Mineralization and Redistribution of Phosphorus in Soils." Alberta Soil Science Workshop. <u>Proceedings of the Western Canada Phosphate Symposium</u>, Calgary, 1980, pp. 276-306.
- 159. Stewart, J.W.B. and R.E. Karamanos, "Phosphorus, Potassium and Micro-Elements in Wheat Production." Slinkard and Fowler (Editors). "Wheat Production in Canada A Review." Proceedings of the Canadian Wheat Production Symposium, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, March 3-5, 1986, pp. 192-226.
- 160. Strong, W.M. and R.J. Soper. "Utilization of Pelleted Phosphorus by Flax, What, Rape and Buckwheat From a Calcareous Soil." Agronomy Journal 65(1973):18-21.

- 161. Strong, W.M. and R.J. Soper. "Phosphorus Utilization by Flax, Wheat, Rape and Buckwheat From a Band or Pellet-Like Application. I. Reaction Zone Root Proliferation. II. Influence of Reaction Zone Phosphorus Concentration and Soil Phosphorus Supply." Agronomy Journal 65(1974):597-605.
- 162. Synghal, K.N., J.A. Toogood and C.F. Bentley. "Assessing Nitrogen Requirement for Some Alberta Soils." <u>Canadian Journal of Soil Science</u>, 39(1959):120-8.
- 163. Tiessen, H., J.W.B. Stewart and C.V. Cole. "Pathways of Phosphorus Transformation in Soils of Differing Pedogenesis." Soil Science of America Journal 48(1984):853-8.
- 164. Tiessen, H., J.W.B. Stewart and J.O. Moir. "Changes in Organic and Inorganic Phosphorus Composition of two Grassland Soils and Their Particle Size Fractions During 60-70 Years of Cultivation." <u>Journal of Soil Science</u> 34(1983):815-23.
- 165. Tisdale, S.L., W.L. Nelson and J.D. Beaton. "Soil Fertility and Fertilizers." 4th Edition, New York: MacMillan Publishing Co. 1985.
- 166. Tokarchuk, J.M. and L. Loewen-Rudgers. "Copper and Molybdenum Nutrition of Forage-Crops." <u>Proceedings of the 26th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1982, pp. 108-122.
- 167. Tokarchuk, J.M. and L. Loewen-Rudgers. "Copper and Molybdenum Nutrition of Forage Crops." <u>Proceedings of the 28th Annual Manitoba Soil Science Meeting</u>, Winnipeg, 1985, pp. 98-111.
- 168. Tucker, T.C. "Diagnosis of Nitrogen Deficiency in Plants."
 Hauck, R.D. <u>Proceedings of a Symposium at Sheffield</u>, Alabama,
 May 25-27, 1982. American Society of Agronomy, Madison,
 Wisconsin, 1984, pp. 249-62.
- 169. Ukrainetz, H., R.J. Soper and M. Nyborg. "Plant Nutrient Requirements of Oilseed and Pulse Crops." Harapiak, J.T. (Editor). A Symposium on Oilseeds and Pulse Crops in Western Canada, Calgary, Western Cooperative Fertilizer Ltd. (1975):325-74.
- 170. University of Manitoba. "Farmer Survey: Report on Findings."

 Department of Agricultural Economics and Farm Management,
 University of Manitoba, Winnipeg, 1988, pending.
- 171. Wagar, B.I., J.W.B. Stewart and J.O. Moir. "Changes With Time in the Forms and Availability of Residual Fertilizer Phosphorus and Chernozemic Soils." <u>Canadian Journal of Soil Science</u> 66(1986):105-19.

- 172. Walker, D.R. and G. Doorenbal. "Soil Sulphate II. As an Index of the Sulphur Available to Legumes." <u>Canadian Journal of Soil Science</u> 52(1972):261-6.
- 173. Walley, F.L. and R.J. Soper. "Effect of Nitrogen Availability on Yield and Symbiotic Nitrogen Fixation in Lentils." Proceedings of the 30th Annual Manitoba Soil Science Meeting, Winnipeg, 1987, pp. 159-64.
- 174. Watt, J. and L. Arthur. "Opportunities and Prospects for Reduced Input Agricultural Systems: Wheat and Canola in the Prairie Provinces." Report to Agriculture Canada. Department of Agricultural Economics and Farm Management, University of Manitoba, Winnipeg, March, 1987.
- 175. Wells, K.L. "Nitrogen Management in the No-Till System."
 Hauck, R.D. (Editor). <u>Nitrogen in Crop Production</u>, May 25-27,
 1982. American Society of Agronomy, Madison, Wisconsin, 1984,
 pp. 535-50.
- 176. Zubriski, J.C. and D.C. Zimmerman. "Effects of Nitrogen, Phosphorus and Plant Density on Sunflowers." Agronomy Journal 66(1974):798-801.

