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LAND RESOURCE SCIENCE

1987 ANNUAL REPORT

UNIVERSITY of GUELPH

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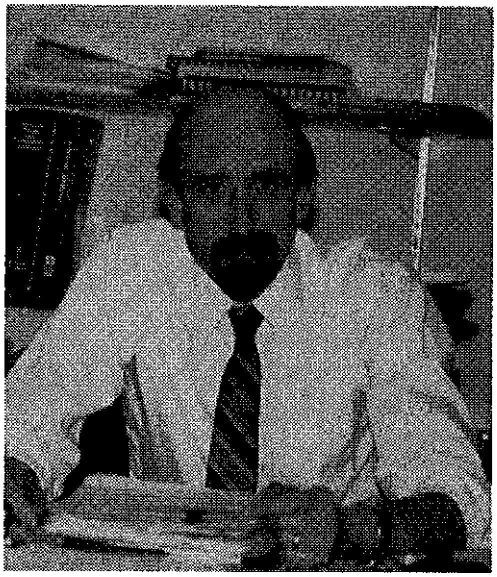
FOREWORD



It is with a great deal of pleasure that I introduce the 1987 Annual Report of the Department of Land Resource Science.

The Report provides an overview of the teaching, research and extension programs carried out in the Department and provides a glimpse of some of the highlights of these programs in the past year. The Report is prepared with several objectives in mind. It includes the most recent information arising from our research and indicates new research thrusts which are being developed. I hope this information will be of value to the users of our research, i.e. other researchers, agricultural advisory personnel, representatives of different government ministries and agribusiness, and members of the public. Information on our educational programs is also included which I hope will be of value to prospective students, teachers, former associates of the Department and others interested in our educational programs. Finally I hope the Report conveys the sense of enthusiasm, creativity and vibrancy which are genuine characteristics of the progress and the people in the Department.

Further information on any of our programs can be obtained by contacting the Department or dropping by in person. Visitors are welcome at any time. Comments on any aspect of our program are always appreciated.

In closing I would like to thank Marilyn Metcalf, Ian van Wesenbeeck and Don Irvine, Andy McLennan and Gabrielle Duval for the typing, editing and graphics associated with preparing this report, thereby making it possible for all of us in Land Resource Science to reach out to you.

B. D. Kay
Chairman

FACULTY/PROFESSIONAL STAFF

B.D. KAY, B.S.A., M.Sc. (Guelph), Ph.D. (Purdue), Professor and Chairman. Physical-chemical reactions in soils, dynamics of frost heaving, influence of tillage and cropping practices on soil structure. (Ext. 2447-8)*.

T.E. BATES, B.S.A. (Toronto), M.Sc. (North Carolina State), Ph.D. (Iowa State), Professor. Fertilizer use and prediction of fertilizer requirements for field crops; micronutrient and metal availability. (Ext. 2452).

E.G. BEAUCHAMP, B.Sc.(Agr.), M.Sc. (McGill), Ph.D. (Cornell), Professor. Nitrogen in the soil/crop system; soil-plant relationships; fertilizers and plant nutrition. (Ext. 3239).

R.A. BOURBONNIERE, B.A. (Massachusetts), M.Sc., Ph.D. (Michigan), Adjunct Professor. Organic geochemistry.

M.E. BROOKFIELD, B.Sc. (Edinburgh), Ph.D. (Reading), Associate Professor. Paleoecology, paleontology, stratigraphy and tectonics. (Ext. 2654).

D.M. BROWN, B.S.A., M.S.A. (Toronto), Ph.D. (Iowa State), Professor. Climate related to land use planning, crop zonation and irrigation feasibility. (Ext. 2206).

W. CHESWORTH, B.Sc., M.Sc. (Manchester), Ph.D. (McMaster), Professor. Geochemistry, petrology, mineralogy, geological mapping. (Ext. 2457).

D.E. ELRICK, B.S.A. (Toronto), M.S., Ph.D. (Wisconsin), Professor. Soil physics; solute and water transport in soils. (Ext. 3758).

L.J. EVANS, B.Sc. (Southampton), Ph.D. (Wales), Associate Professor. Soil chemistry and clay mineralogy. (Ext. 3017).

C.A. FITZGIBBON, B.A. (McMaster), M.Sc. (Saskatchewan), Co-ordinator of O.I.P. Computer Laboratory and Teaching Associate. Soil science, resources planning and management. (Ext. 3393).

T.J. GILLESPIE, B.Sc. (British Columbia), M.S.A. (Toronto), Ph.D. (Guelph), Professor. Relationship of plant diseases and pests to weather; computer modelling of soil and air microclimates. (Ext. 2645).

W.A. GLOOSCHENKO, B.S. (California, Berkeley), M.S. (California, Davis), Ph.D. (Oregon), Adjunct Professor. Vegetation ecology and geochemistry of wetlands.

P.H. GROENEVELT, M.Sc., Ph.D. (Wageningen), Professor. Applied soil physics, erosion, soil structure. (Ext. 3585).

S.G. HILTS, B.A. (Western Ontario), M.A. (Toronto), Ph.D. (Toronto), Associate Professor. Joint appointment with University School of Rural Planning and Development. Natural resources management, environmental planning, land utilization. (Ext. 2702).

R.G. KACHANOSKI, B.Sc., M.Sc. (Saskatchewan), Ph.D. (California, Davis), Assistant Professor and Co-ordinator of Extension. Soil physics, soil and water conservation and extension. (Ext. 2498).

G.E. KIDD, B.A.Sc., M.A.Sc. (Waterloo), Professional Assistant. Electronic instrument development; transport processes within and above plant canopies. (Ext. 3434).

K.M. KING, B.S.A. (Toronto), M.S., Ph.D. (Wisconsin), Professor. Agrometeorology; evapotranspiration and photosynthesis of field crops and forests; effects of elevated atmospheric CO_2. (Ext. 2787).

PERSONNEL

Land is a simple term used to describe a complex feature of the earth's surface, a feature that includes the solid earth, soil, water, plants and the lower atmosphere. The teaching, research and educational programs in the Department all have a central focus - more effective use of our land resources. The disciplines in the Department which contribute to this focus are agrometeorology, soil science, geology and land use planning. The interests and strengths of each member of the Department are outlined in the following list of personnel.

During the past year several members of the Department received awards or have been recognized by other means for their contribution to teaching, research and service related to land resource science. Foremost among such awards was the designation of Dr. R.L. Thomas as one of the University of Guelph Distinguished Teachers and recognition by the O.A.C. Alumni Association as the Distinguished Teacher in 1987. Several faculty have been asked to serve on Editorial Boards of internationally recognized research journals. Among faculty so honoured in 1987 were Dr. P.H. Groenevelt (Editor-in-Chief, Journal of Soil and Tillage Research), M.H. Miller (Associate Editor, Canadian Journal of Soil Science), L.J. Evans (Associate Editor, Canadian Journal of Soil Science), D.E. Elrick (Associate Editor, Journal Contaminant Hydrology), M. Brookfield, (Editor, Bulletin of the Indian Geological Society, and T.E. Bates (Associate Editor, Journal of Environmental Quality). Several faculty served on a number of advisory committees at the provincial and national level. At the international level Dr. P.H. Groenevelt was appointed to the International Board of the Soil Tillage Research Organization. Dr. P. van Straaten and Dr. W. Chesworth were invited by the International Development Research Centre to assist in setting up a project in Ethiopia. Dr. W. Chesworth was invited to present a paper on geology in agriculture at the Fourteenth Colloquium on African Geology in Berlin. Several faculty were invited to present seminars to researchers in universities and government laboratories in a number of locations in Canada and outside of Canada. Faculty were also invited to contribute to the teaching and extension programs in other countries.

Mr. Dirk Tel was invited by CIDA to offer a course on analytical techniques used in soil science. The course which was six weeks in duration was given at the International Institute of Tropical Agriculture in Ibadan, Nigeria. Mr. Tel was assisted by Dr. P.H. Groenevelt.

Dr. D. Reynolds (a former Ph.D. student with Dr. D.E. Elrick) was awarded the Emil Truog Award by the Soil Science Society of America as the most distinguished Ph. D. thesis in 1986. Part of Dr. Reynold's thesis related to the development of the Guelph Permeameter which was awarded "The Agricultural Engineering 50" award for outstanding innovations in products or systems technology during 1986-87. This award was presented by the American Society of Agricultural Engineering.

The achievements of the past year can be traced to the initiative, enthusiasm and creativity of all members of the department. Special acknowledgement is due to the technical and clerical staff whose continued support is reflected in the excellence of our teaching, research and service programs.

B.C. MATTHEWS, B.S.A. (Toronto), A.M. (Missouri), Ph.D. (Cornell), D.U. (Sherbrooke), L.L.D. (Waterloo), Professor. Soil chemistry. President and Vice-Chancellor. (Ext. 2200).

I.P. MARTINI, Doct. Geol. Sci. (Florence), Ph.D. (McMaster), Professor. Sediments and sedimentary rocks, sedimentology, glacial geology. (Ext. 2488).

T.P. MCGONIGLE, B.Sc. (Sussex), D.Phil. (York), Scientist. Vesicular-arbuscular mycorrhizas and their effect on plant growth. Commenced duties November 16, 1987. (Ext. 8748).

R. MCBRIDE, B.Sc., Ph.D. (Guelph), Assistant Professor. Soil science and agricultural land use planning. (Ext. 2492).

M.H. MILLER, B.S.A. (Toronto), M.S., Ph.D. (Purdue), Professor. Soil fertility, plant nutrition and soil conservation. Director, Centre for Soil and Water Conservation. (Ext. 2482).

W.A. MITCHELL, Administrative Technical Officer. Controlled environment plant growth facilities. (Ext. 2484).

E. PERFECT, B.Sc. (Newcastle-upon-Tyne), M.A. (Carleton), Ph.D. (Cornell), Post Doctoral Fellow. Effect of cropping systems and ground freezing on soil structure. (Ext. 2489)

R. PROTZ, B.S.A., M.S. (Saskatchewan), Ph.D. (Iowa State), Professor. Soil genesis and classification; soil variability; soil clay mineralogy; mapping techniques and soil landform relationships. (Ext. 2481).

B. SCHNELLER, B.S.A. (Toronto), M.S. (Cornell), Manager, Agroclimatology Program, Plant Industry Branch, Ontario Ministry of Agriculture and Food. (Ext. 2480).

R.W. SHEARD, B.S.A. (Saskatchewan), M.S.A. (Toronto), Ph.D. (Cornell), Professor. The agronomy of crop production of cereals and forage. (Ext. 2491).

G.A. SPIERS, B.Sc. (Waikato), M.Sc. (Alberta), Research Associate. Mineralogy, geochemistry and pedology. (Ext. 2489).

E.P. TAYLOR, B.Sc.(Agr.) (Guelph), Research Associate. Forest Pedology. Resigned Dec. 24, 1987.

R.L. THOMAS, B.Sc., M.Sc. (Alberta), Ph.D. (Ohio State), Professor. The chemical characterization and reactions of soil organic matter. (Ext. 2459).

G.W. THURTELL, B.S.A., M.S.A. (Toronto), Ph.D. (Wisconsin), Professor. Physics of soils, plant and atmosphere. (Ext. 2453).

H.P. VAN STRAATEN, Dipl. Geol., Dr. rer. nat (Gottingen, Germany), Research Associate. Geology, mineral exploration, agrogeology in East Africa. (Ext. 2454).

R.P. VORONEY, B.Sc. (Calgary), M.Sc., Ph.D. (Saskatchewan), Assistant Professor. Soil biological activity, soil management. (Ext. 3057).

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*Extension number (e.g. Ext. 2447) at the University of Guelph. University of Guelph phone number is (519) 824-4120.

CLERICAL/TECHNICAL STAFF

K. ALEXANDER, B.Sc. (Mount Allison), M.E.S. (Dalhousie), Research Assistant (part-time). Maximum corn yield research. (Ext. 8593).

R.D. BALDWIN, B.Sc. (Guelph), Forestry and Pedology Technologist. (Ext. 3488).

N. BAUMGARTNER, Assoc. Dipl. Agr. (Guelph), Teaching and Laboratory Technician. Soil physics. (Ext. 8556).

P.E. BEIRNES, Administrative Secretary. (Ext. 2448).

R. BERARD, B.S.A. (St. Boniface), M.Sc. (Manitoba), Research Assistant (part-time). Soil plant water relations. (Ext. 2487).

L. BISSELL, Clerk. (Ext. 2661).

D. BRENNER, Secretary. Extension. (Ext. 6364).

J.C. BRYANT, Assoc. Dipl. Agr. (Guelph), Technician. Soil management plot work and field equipment fabrication. (Ext. 2617).

J. CUTHILL, B.Sc.(Agr.) (Guelph), Project Co-ordinator. Slow rate infiltration land treatment of landfill leachate. (Ext. 2565).

E.L. DICKSON, Dipl. Chem. Tech. (St. Clair, C.A.A.T.), Technician. Runoff collection and analysis, research analytical laboratory. (Ext. 2494).

M.R. EVANS, B.Sc. (Waterloo), Certif. Comp. and Info. Sci. (Guelph), Technician. Computer data analysis. (Ext. 2493).

J.A. FERGUSON, Assoc. Dipl. Agr. (Guelph), Technician. Soil management data acquisition and statistical analysis. (Ext. 2617).

E.F. GAGNON, Assoc. Dipl. Agr. (Guelph), Supervisor. Analytical Services Laboratory. (Ext. 2494).

D.E. IRVINE, Chartered Cartographer (Ont. Inst. Ch. Cart.), Cartography, Desk top publishing and computer graphics. (Ext. 3364).

S. LAYCOCK, Secretary. Undergraduate and graduate programs. (Ext. 2456).

D. LEE, B.Sc. and M.Sc. (Guelph), Technician. Analytical Services Laboratory. (Ext. 2494).

D.A. LOBB, B.Sc. (Toronto), Research Assistant. Soil and water conservation. Commenced duties May 11, 1987. Centre for Soil and Water Conservation. (Ext. 2484).

J. LOVCANIN, B.Sc. (Belgrad), Technician. Soil management and plant nutrition field plot. (Ext. 6371).

J.A. MCLENNAN, Assoc. Cart. (Ont. Inst. Ch. Cart.), Technician. (Ext. 3364).

P.M. MCLENNAN, Assoc. Dipl. Environ. Eng., Forester. Forestry and Pedology Technologist. Resigned May 15, 1987.

M.J. METCALF, Secretary. (Ext. 6365).

T. MOULL, B.Sc.(Agr.), M.Sc. (Guelph), Research Associate. Natural Heritage Stewardship Project Co-ordinator. (Ext. 8329).

C. PALMER, B.Sc.(Agr.) (Guelph), Soil Analysis Assistant. (823-5700 Ext. 330).

L.A. PODMORE, Stenographer. Resigned June 30, 1987.

J.A. POISSON, B.Sc. (Guelph), Technician. Soil chemistry/biochemistry. (Ext. 8157).

V. RASIAH, B.Sc. (Ceylon), M.Sc., Ph.D. (SDSU), Research Assistant. Enhancing biodegradation of industrial wastes. Commenced duties March 1, 1987. (Ext. 2487).

J.A. RZADKI, B.Sc. (Toronto), M.Sc. (Guelph), Research Assistant. Natural Heritage Stewardship Project. Assistant Co-ordinator. (Ext. 8329).

S. SADURA, B.Sc.(Agr.) (Guelph), Teaching and laboratory technician. Information technology. (Ext. 3393).

J.K. SCARROW, Secretary/Clerk. Commenced duties October 21, 1987. (Ext. 2455/2661).

P. SMITH, B.A. (Guelph), Technician. Geochemistry. (Ext. 8175).

L.A. STAHLBAUM, Technician. Soil classification. (Ext. 8170).

R.E. SWEETMAN, Dipl. Elec. Eng. (R.E.T.S., Detroit), Technician. Agrometeorology, electronic instrumentation, data acquisition and processing, field experiments. (Ext. 2208).

K.A. TAN, B.Sc.(Eng.), M.Sc. (Guelph), Research Assistant. Soil physics. Resigned January 7, 1988.

G. TAYLOR, Assoc. Dipl. Agr. (Guelph), Technician. Soil management and plant nutrition plot work. Resigned August 31, 1987.

D. TEL, Dipl. Agr. (Oedekerk), Dipl. Agr. College (Groningen), Technician. Supervisor, Research Analytical Laboratory. Lab. Instructor for Soil Chemistry. Soil, plant and water analyses. (Ext. 3507).

M. VAN PATTER, B.Sc.(Agr.), M.Sc. (Guelph), Research Assistant. Natural Heritage Stewardship Project. (Ext. 8329).

P. VON BERTOLDI, Agr. Eng. (Argentina), M.Sc. (UCD), Technician. Soil management and plant nutrition plot work. Commenced duties July 15, 1987. (Ext. 8106).

W.G. WILSON, B.Sc. (Guelph), Technician. Soil chemistry, biology and clay mineralogy. (Ext. 8157).

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*Extension number (e.g. Ext. 2447) at the University of Guelph. University of Guelph phone number is (519) 824-4120.

UNDERGRADUATE EDUCATION

The Land Resource Science Department offers undergraduate education programs leading to the Bachelor of Science degree or the Bachelor of Science in Agriculture degree. The B.Sc. degree is received by students majoring in Earth Science, which emphasizes an understanding of the physical and chemical processes near the earth's surface. Course work includes near-surface geology, geomorphology, weathering, soil physics and chemistry, and meteorology. Soil Science majors focus on the fundamental science and management of our soil resources, and receive the B.Sc. (Agr.) degree. The remaining B.Sc. (Agr.) students in our Department are enrolled in the Resources Management major. Knowledge about the nature, economics and management of rural resources with a strong biophysical foundation, is emphasized.

A new thrust into Co-operative Education was introduced as an option for the Resources Management major in 1987. Students may elect to begin the first of four work semesters in the summer of 1988. These work semesters with government ministries, conservation authorities and environmental consultants will provide students with first hand exposure to realistic resources problems and potential future employers. Additionally, a forestry course will now be included in the core of Resources Management.

With some reorganization of material in the courses "Soil and Water Conservation" and "Waste Management and Land Reclamation", increased emphasis has now been placed on the role of soil biology in these areas. Further strengthening of our emphasis on soil management for conservation, reclamation and waste disposal is anticipated for the near future.

To encourage interaction between the three undergraduate majors in our Department, we have made two changes in our teaching program. Earth Science students are now being encouraged to join Soils and Resources Management students in the course "Problem Solving in Land Resource Science". A major objective of this second year offering is to teach skills in communication, interdisciplinary group work and problem solving. Also, the students and activities previously taught separately in "Current Resources Management Issues" and "Issues in Soil Science" have been combined and retitled "Issues in Land Resources". This is an integrating course at the fourth year level which may consider a broad range of practical problems involving characterization, inventory, use and management of land.

Undergraduate Diploma and Degree Courses Offered During 1987.

Course Numbers	Courses	Enrolment
Diploma		
87-010	Principles of Soil Science	155
87-011	Soil Management for Crop Production	144
Degree		
01-140	The Agriculture and Food System I	266
01-300	Field Trip in International Agriculture	15
46-100	Principles of Geology (Fall and Winter)	51
46-104	Study of the Earth	215
46-202	Stratigraphy	9
46-205	Glacial Geology	9
46-210	Mineralogy	11
46-250	Remote Sensing	15
46-306	Hydrogeology	29
46-307	Petrography	7
46-310	Geochemistry and Geology of Fossil Fuels	12
46-318	Geochemistry	12
46-404	Geology of Canada	4
46-409	Sedimentology	5
46-411	Topics in Earth Science	10
46-412	Topics in Earth Science	1
64-203	Meteorology and Climatology	3
64-302	Agrometeorology	17
64-305	Microclimatology	18
64-416	Intermediate Meteorology	6
87-201	Soil in Planned Environments	46
87-250	Problem Solving in Land Resource Science	24
87-302	Soil Genesis and Classification	20
87-305	Land Utilization	33
87-308	Soil & Water Conservation	34
87-310	Resources Planning and Management	11
87-311	Resources Field Camp	13
87-350	Land & Water Use in Tropical Countries	28
87-401	Soil Chemistry	19
87-402	Soil Physics	24
87-405	Soil Management	27
87-407	Problems in Land Resource Science	3
87-409	Soil Management	1
87-410	Soil Plant Relationships	27
87-412	Current Resources Management Issues	14
87-415	Decision Making in Resources Management	16
87-420	Issues in Soil Science	7

GRADUATES IN SOIL SCIENCE, RESOURCES MANAGEMENT AND EARTH SCIENCE

JUNE, OCTOBER 1987, AND FEBRUARY 1988

SOIL SCIENCE MAJORS

Patrick Toner
Timothy Allen
John Cline
David Hodgson
Mark Janiec
Helen Lammers
Maryann McLean
David Stanley
William Stevens
Gordon Tyl
Michael Kelly
Deborah Milne

RESOURCE MANAGEMENT MAJORS

Pam Blair
Jim Cuthill
Lisl Boegman
Roger Daly
Shelley Delaney
Brenda Grant
Stephen Hamilton
Glenn Hulkowich
David Hunter
Karina Lechner
Brian McMahon
Elizabeth Pringle
Christopher Shrive
Karin Smith
Jon Watchurst
Michael White
Dagmar Woll
Marie Baker
Marnie Murray

EARTH SCIENCE MAJORS

Cecilia Howkins
Asiah Mohd Salih
Colin Sim
Rosa Velasco
Sue Bradley
Sandra Jones
David Pesce
Mark Smith
James Thompson
Eleanor Mancinelli
Scott Newlove
Derek Stewart
Brian Watson

DEAN'S HONOUR ROLL - 1987

Students with a minimum of 80% average and in the top 10% of their class
(W - winter semester, F - fall semester)

Marie Baker (F)	Resources Management
Ron Beyaert (F)	Soil Science
Patrick Hill (W)	Earth Science
Andrew Jarrette (W,F)	Resources Management
Helen Lammers (W)	Soil Science
Christine Lane-Smith (W)	Soil Science
Mary Ann McLean (W)	Soil Science
Deborah Milne (W)	Soil Science
David Pesce (W)	Earth Science
Mira Racki (F)	Earth Science
Karin Smith (W)	Resources Management
Brian Watson (W)	Earth Science

UNDERGRADUATE CONVOCATION AWARDS - JUNE 1987

O.A.C. Proficiency Prize (B. Sc.)	Susan Bradley Earth Science
Class of '76 Graduation Prize	Dagmar Woll Resources Management
N.R. Richards Scholarship	Helen Lammers Soil Science

IN-COURSE AWARDS

UNDERGRADUATEOCTOBER 1987

John A. Archibald Memorial Scholarship	Ron Beyaert Soil Science
Lewis S. Johnson Scholarship	Sandra Neeson Resources Management
Robert Harcourt Scholarships	Ron Beyaert Soil Science
	Christine Lane-Smith Soil Science
Barkley's of Avonmore Scholarship	Jennifer Ballantine Resources Management

GRADUATE EDUCATION

The Department offers a wide range of opportunities for graduate studies at the Master's and Ph.D. levels. The M.Sc. programs are available in Agrometeorology, Soil Science and in Resources Development (in conjunction with the University School of Rural Planning and Development). A M.Agr. program is offered in Land Management and Agricultural Land Use. Ph.D. programs are available in Agrometeorology and Soil Science. The Department also participates in the interdepartmental groups on Biophysics, Hydrology, Plant Physiology and Toxicology whereby a student, registered in the Department, may enrol and specialize in one of those disciplines.

Financial assistance in the form of scholarships, research assistantships and teaching assistantships are available to qualified students. Research facilities available include well equipped laboratories for agrometeorology, soil chemistry, soil mineralogy, soil physics, soil biology and plant nutrition. Research instrumentation includes x-ray diffraction, mass spectrometry, liquid and gas chromatographs, sonic anemometry, gas analysers, data loggers and agrometeorological field equipment. Greenhouses, growth chambers and 50 ha of field research plots are available for research projects. A graduate student has the opportunity to work with faculty in one of the many research projects underway in the Department. For further information contact the faculty members in the relevant area of interest or the Graduate Co-ordinators in Agrometeorology or Soil Science.

GRADUATE EDUCATION

Graduate students and supervisors - Winter Semester, 1988.

Soil Science Program

M.Sc. Students	Supervisors	Ph.D. Students	Supervisors
Alder, V.	R.W. Sheard	Alexander, K.	M.H. Miller
Bolton, K.L	L.J. Evans	Barry, D.	M.H. Miller
Braunberger, P.	M.H. Miller	Campbell, A.	D.E. Elrick
Brogly, P.	I.P. Martini	Caron, J.	B.D. Kay
Crabtree, D.	W. Chesworth	Drury, C.	E.G. Beauchamp
Cruickshank, C.	L.J. Evans	Evans, D.	M.H. Miller
Cureton, P.	P.H. Groenevelt	Fairchild, G.	M.H. Miller
Dongol, G.	M. Brookfield	Gregorich, E	R.G. Kachanoski
Farquharson, B.	E.G. Beauchamp	Lu, S.	M.H. Miller
Flather, D.	E.G. Beauchamp	Paul, J.	E.G. Beauchamp
Hamlen, C.	R.G. Kachanoski	Sweeney, S.	R. Protz
Hart, R.	M.H. Miller	Winter, J	R.P. Voroney
Jensen, F.	L.J. Evans	Zhang, C.Y.	T.E. Bates
Johnson, T	P.H. Groenevelt		
Jones, S.	D.E. Elrick		
Liu, L.	T.E. Bates		
Lobb, D.	M.H. Miller		
McCabe, D.	R. Protz		
Mott, S.	P.H. Groenevelt		
Nurwadjedi	R. Protz		
Penny, R.	R.P. Voroney		
Pojasok, T.	B.D. Kay		
Proud, B.	R. Protz		
Shrive, C.	R.A. McBride		
Su, C.	L.J. Evans		
Ward, A.	R.G. Kachanoski		
Webster, A.	I.P. Martini		
Wen, G.	R.P. Voroney		
Young, D	P.H. Groenevelt		
Zhai, R.	R.G. Kachanoski		
Zhang, X.	E.G. Beauchamp		
Zhu, Z.Y.	T.E. Bates		

Agrometeorology Program

M.Sc. Students	Supervisors	Ph.D. Students	Supervisors
Biring, B.	K.M. King	Barr, A.	T.J. Gillespie
Fuentes, J.	K.M. King	Berard, R.	G.W. Thurtell
Lin, P.	G.W. Thurtell	Edwards, G.	G.W. Thurtell
McLean, H.	K.M. King	Groot, A.	K.M. King
Singh, G.	D.M. Brown	McGinn, S.	K.M. King
Zhang, Y.	T.J. Gillespie		

Resources Development

University School of Rural Planning and Development

Connolly, S.	S.G. Hilts
O'Neill, B.	R.A. McBride
Sribimawati, T.	D.M. Brown

Masters of Agriculture

Taylor, P.F.	R.A. McBride

GRADUATE DEGREES CONFERRED JUNE, OCTOBER 1987 AND FEBRUARY 1988.

Student	Degree	Supervisor	Thesis Title	Defence Date
Soil Science Program				
S. Abboud	Ph.D.	T.E. Bates	Chemical forms of cadmium in municipal sewage sludge amended-soils	March 17 1987
S. Lu	M.Sc.	M.H. Miller	The role of mycorrhizae in the absorption of P and Zn by maize (Zea mays L) in field and growth chamber experiments	Dec. 14 1987
A. Ovid	M.Sc.	P.H. Groenevelt	The effects of accelerated erosion on corn yields on a Guelph loam	Jan. 30 1987
N. Richards	M.Sc.	D.E. Elrick	A comparison of three methods for measuring hydraulic parameters of field soils	July 9 1987
A. Seech	M.Sc.	E.G. Beauchamp	Denitrification in soil aggregates of different size	Nov. 23 1987
R. Simard	Ph.D.	T.E. Bates	Effects of $CaCO_3$ and P additions on soil chemical characteristics and corn growth on a podzolic soil	Apr. 30 1987
R. Tossell	M.Sc	P.H. Groenevelt	A comparison of three methods used to characterize simulated rainfall properties	Mar. 19 1987

I. van Wesenbeeck	M.Sc.	R.G. Kachanoski	Spatial and temporal dynamics of soil-water content under a corn crop	Sept. 22 1987

Agrometeorology Program

P. Hopps	Ph.D.	G.W. Thurtell	(Awarded post-humously)	June 4 1987
J. Fuentes	M.Sc.	K.M. King	Leaf photosyn thesis, leaf con-ductance and intercellular CO_2 concentra-tion of maize grown hydropon-ically and in soil	May 21 1987
M. Kalliomaki	M.Sc.	T.J. Gillespie	The water re-tention character-istics, and re-sistances to water loss and water up-take, of dead winter wheat tissue	Sept. 21 1987
M. Leclerc	Ph.D.	G.W. Thurtell	Turbulence and turbulent diffusion inside and above vegetation	Aug. 18 1987
G. Shi	M.Sc.	G.W. Thurtell	Studies of atmos-pheric turbulence within and above a deciduous forest	July 23 1987

LAND RESOURCE SCIENCE AWARD

Morwich Scholarship - June 1987	David Evans

GRADUATE STUDENTS AWARDS - OCTOBER 1987

Soden Fellowships in Agriculture	Alan Barr David Evans
Mary Edmunds Williams Fellowship	Stella Mott
Natural Science and Engineering Research Council Fellowship	Alan Barr
Ontario Graduate Scholarship	John Paul

DAVISON TRAVEL GRANTS

Ian van Wesenbeeck	Gordon Fairchild
Kim Bolton	Jose Fuentes
Stella Mott (2)	Terrence Johnson
Philippa Cureton	Sean McGinn
Alan Barr	John Paul
Dean Barry	Taras Pojasok
Raymond Berard	Chunming Su
Craig Drury	Julien Winter
David Crabtree	

OTHER AWARDS

C.F. Bentley Award of the Canadian Society of Soil Science

John Paul (1st)
Ian van Wesenbeeck (2nd)
Craig Drury (3rd)

EXTENSION HIGHLIGHTS

R.G. Kachanoski

The extension program of the Land Resource Science Department is designed to transfer and encourage application of research based knowledge related to the wise use of our land resource. The department offers services to farmers, the agriculture industry, and government through specialized education programs, provision of resource persons, expert response for solving problems and answering technical requests, stimulation of the process of problem identification, and preparation of technical information in an extension format for publication.

Extension activities accounted for 1.3 man-years or 287 days in 1987 (Table 1). Faculty participated in educational programs such as the Land Stewardship Workshop which attracted over 150 farmers, agribusiness, and government personnel. The annual Soil Fertility Workshop sponsored jointly by the Department of Land Resource Science, the Fertilizer Industry of Ontario, and the Ontario Ministry of Agriculture and Food continues to be a major source of information and updating of research results for agribusiness and farmers.

Once again significant extension time was spent working with the Soil and Water Management Branch (OMAF) and the Soil Conservation Advisors, delivering on-farm practical conservation information, advice, and technical assistance to Ontario producers. Tillage-2000, an on-farm conservation program sponsored jointly by OMAF, Land Resource Science, and the Ontario Soil and Crop Improvement Association completed its second year with excellent results. Approximately 40 farm cooperators were associated with the program in 1987. The department also played a significant role in many workshops, committees and planning sessions associated with the Federal-Provincial Soil and Water Environmental Enhancement Program (SWEEP). The SWEEP program is a major extension-research effort aimed at reducing the phosphorus and sediment loads to the Great Lakes.

Dr. Murray Miller from the department was appointed the director of the new Soil and Water Conservation Centre at the University of the Guelph. The Centre will provide a focus for research in the area of conservation and the department will continue its extension efforts in this area.

Table 1. Summary of Land Resource Science Extension Activities in 1987.

	Total Ext. Days	% of Total Ext. Effort
Courses, conferences, etc.	89	31
Consultations	111	39
Ext. Committees	32	11.5
Publications and Ext. Materials	29	10.0
Public Relations	5	1.5
Other Activities	21	7.0
Total	287	100.0

*Represents 1.3 man-years @ 220 days/yr

RESEARCH SUMMARY

B.D. Kay

Research programs in the Department of Land Resource Science continue to be responsive to the needs of those responsible for the management of our land resources. A major goal of this research is the development of management practices which will sustain the long-term use of our resources by society. Progress towards this goal is facilitated by research directed to increasing our understanding of the fundamental characteristics land resources.

The total value of grant and contracts supporting research in Land Resource Science in 1987 was in access of two million dollars. This represented included $1,033,317.00 from the Ontario Ministry of Agriculture and Food and more than one million dollars from other agencies. The latter agencies included Natural Sciences and Engineering Research Council, Agriculture Canada, Atmospheric Environment Service, Environment Canada, Indian Affairs and Northern Development, Research Advisory Board, University of Guelph, International Development Research Centre, Canadian National Sportsmen's Shows, Laidlaw Foundation, The McLean Foundation, The Nature Conservancy of Canada, The Ontario Heritage Foundation, Wildlife Habitat Canada, World Wildlife Fund, Ontario Turfgrass Foundation, Ontario Ministry of the Environment, Ontario Ministry of Energy, Ontario Ministry of Natural Resources, and Cyanamid Canada Limited.

The level of funding for research has progressively grown; the current level of funding (excluding service charges) is 8.4% greater than that provided in 1986. The funding which is provided by research sponsors is crucial to a dynamic program which remains at the "cutting edge" of new developments.

Details on research projects which were completed in 1987 are outlined in the following pages. The reports are summarized into three groups:

1) Land Characterization,
2) Land Management,
3) Land Planning.

Such a grouping is intended to illustrate how the disciplines of soil science, geology, agrometeorology and land use planning interact in solving problems related to land resources. An index by authors appears at the end of this Report.

CURRENT RESEARCH PROJECTS AND FUNDING SOURCES

Faculty	Title of Project	Funding Agency
T.E. Bates	Development and evaluation of methods for prediction of macro- and micronutrient requirements of crops	O.M.A.F. N.S.E.R.C.
T.E. Bates	Use of sewage sludge on agricultural land with emphasis on plant availability of heavy metals	O.M.A.F.
T.E. Bates	Evaluation of effects of deicers on soil, turf and shrubs	Domtar Ltd.
N. Baumgartner	Undergraduate Teaching Equipment	O.A.C. Dean's Excellence Fun(
E.G. Beauchamp	Dicyandiamide as a nitrification inhibitor	Cyanamid Canada Ltd.
E.G. Beauchamp	Manure as a source of nitrogen	O.M.A.F.
E.G. Beauchamp	Availability of soil N in southern Ontario	O.M.A.F.
E.G. Beauchamp	Denitrification of soils	N.S.E.R.C.
M.E. Brookfield	Mesozoic evolution of the Himalayas	N.S.E.R.C.
D.M. Brown	Comparison of rainfall distribution during dry spells using radar images and gauge networks	Atmospheric Env Services, W.U.S.C., O.M.A.F.
D.M. Brown M.E. Dixon	Scheduling irrigation for optimum water use and yield of potatoes	O.M.A.F.
W. Chesworth	Geochemistry of weathering	N.S.E.R.C.
W. Chesworth P. van Straaten	The Guelph-Morogoro (Tanzania) agrogeology project (second phase)	International Research Centre
D.E. Elrick	Transport phenomena in natural porous media	N.S.E.R.C.
D.E. Elrick	Water and chemical transport in soils	O.M.A.F.

L.J. Evans	Boron in Ontario soils	O.M.A.F.
L.J. Evans	Charge characteristics of Ontario soils	O.M.A.F.
L.J. Evans	Chemistry of Fe and Al in soils	N.S.E.R.C.
T.J. Gillespie	Measurement and estimation of crop microclimates for pest management	O.M.A.F.
T.J. Gillespie	Investigation of planetary boundary layer models to estimate regional scale climates	N.S.E.R.C.
P.H. Groenevelt	Effect of erosion on soil properties and corn yield	O.M.A.F.
P.H. Groenevelt	Physical properties of soils under intensive cultivation	N.S.E.R.C.
S.G. Hilts	Assessment of sources of motivations for farm conser-vation decisions	Ag. Canada
S.G. Hilts	Natural heritage stewardship project	Ontario Heritage Foundation, MNR, Canadian National Sports-men's Shows, Wildlife Habitat Canada, Nature Conservancy of Canada, McLean Foundation, Laidlaw Found-ation, W.W.F., Coalition of the Niagara Escarp-ment
S.G. Hilts D.M. Brown R.A. McBride	Development of a rating system to evaluate agricultural land at the local level	O.M.A.F.
S.G. Hilts	Soil-vegetation relationships in the wetlands of Southern Ontario	Undergraduate Student Scholarships from N.S.E.R.C.
R.G. Kachanoski	Tillage effects on the spatial and temporal variations of soil properties	N.S.E.R.C

R.G. Kachanoski	Nitrogen response under conservation tillage	O.M.A.F.
R.G. Kachanoski	Use of electro-magnetic induction measurements of soil resistance for medium scale variability assessment	N.S.E.R.C.
R.G. Kachanoski R.P. Voroney	Effects of conservation tillage on bio-physical relationship on soil	O.M.A.F.
R.G. Kachanoski M.H. Miller D. Aspinall	Relationships between landform, soil, and tillage systems, on erosion rates and crop yield	O.M.A.F. Ag. Canada (SWEEP)
R.G. Kachanoski	Variable applications of fertilizers	O.M.A.F. N.S.E.R.C.
B.D. Kay	Quantitative characterization of heat, water and solute transport in freezing soils	N.S.E.R.C.
B.D. Kay P.H. Groenevelt	Development of methodology to characterize some physical properties of soils under different tillage treatments	O.M.A.F.
K.M. King	Effects of elevated atmospheric CO_2 on agriculture	O.M.A.F. Env. Canada Min. of Energy
K.M. King	CO_2 flux to a forest	Atmospheric Env. Service
K.M. King T.J. Gillespie	Acquisition and compilation of agroclimatological data	O.M.A.F.
I.P. Martini	Effects of river ice on sediment transport	N.S.E.R.C., Min. of Indian & Northern Affairs
I.P. Martini	Quantitative analysis of of sands and sandstones	N.S.E.R.C.
I.P. Martini	Comparative analysis between recent cold climate peats and ancient coal measures	N.S.E.R.C
R.A. McBride A.M. Gordon (Env. Biol.) P.H. Groenevelt	Treatment of landfill leachate by spray irrigation- Muskoka Lakes	Ministry of the Environment

R.A. McBride	Development of a rating system for soil compaction susceptibility	Research Board
R.A. McBride	Soil compaction and crop yield	Ontario Hydro
R.A. McBride	Aberfoyle Creek (Agric. Productivity)	Research Excellence Fund
R.A. McBride A.M. Gordon P.H. Groenevelt L.J. Evans T.J. Gillespie	Slow rate infiltration land treatment and recirculation of landfill leachate in Ontario	Ministry of the Environment
M.H. Miller G.W. Thurtell K.M. King E.G. Beauchamp	Modifying soil plant environment to maximize yield potential of maize	N.S.E.R.C.
M.H. Miller	Reactions at the soil-root interface and their significance in plant nutrition	N.S.E.R.C.
M.H. Miller W.A. Mitchell D. Lobb	Methods of application of fertilizer at planting for corn in conservation tillage systems	O.M.A.F. Potash Phosphate Institute of Canada, Fertilizer Inst. of Ontario
M.H. Miller R.G. Kachanoski D. Lobb	Severe erosion on shoulder slopes: causes and control	Dept. of Supply and Services (SWEEP-TED)
R. Protz	Influence of clay content on on clay weathering and morphology of soils in the Lake Erie Basin	N.S.E.R.C.
R. Protz	Implementation of Landsat and Spot satellite resource data into a microcomputer based county level geographic information system	O.M.A.F./ A.R.I.O.
R. Protz	Development of an index of soil quality	O.M.A.F.
R.W. Sheard	The enhacement of protein in wheat through efficient use of N and other cultural practices	O.M.A.F. C.I.L. Inc. U.C.O. Ciba-Geigy T.F.I.D.

R.W. Sheard	Forage systems as nitrogen sources in crop production	O.M.A.F.
R.W. Sheard	Interactions of soil drainage, species and plant nutrition	O.M.A.F.
R.W. Sheard	Soil test calibration for major field crops	O.M.A.F.
R.L. Thomas	Study of organic constituents in stable soil micro-aggregates	N.S.E.R.C. O.M.A.F.
G.W. Thurtell	Soil-plant-atmosphere	N.S.E.R.C.
G.W. Thurtell	Turbulent diffusion	A.E.S. O.M.A.F.
G.W. Thurtell	Soil-plant-water relationships	O.M.A.F.
R.P. Voroney P.H. Groenevelt R.G. Kachanoski L.J. Evans T.E. Bates	Industrial waste management through enhanced land treatment	N.S.E.R.C. I.C.S.T.
R.P. Voroney P. van Straaten W. Chesworth T. Bates J. Eggens	Use of natural zeolites to improve turfgrass establishment, growth and maintenance in sand root zones for putting greens	Ont. Turfgrass Research Found.
R.P. Voroney	Conservation village effects on the decomposition of crop residues	N.S.E.R.C.
R.P. Voroney	Biological and chemical degradation of the herbicide CGH-5600	Ciba-Geigy Canada Ltd.
R.P. Voroney	Crop residue management and phytotoxin effects under conservation tillage	O.M.A.F.
R.P. Voroney	Identification of soil management and cropping practices which sustain the capability of a soil to accept, cycle and store organic matter	O.M.A.F.
R.P. Voroney	Development of computer-assisted teaching modules in soil science	N.S.E.R.C.

R.P. Voroney	Long-term tillage effects on soil biology	N.S.E.R.C.

LAND CHARACTERIZATION

THE GROWTH OF THE UNSTABLE, PLANETARY BOUNDARY LAYER

A. Barr and T.J. Gillespie

Preliminary to investigating the interaction between the growth of the daytime, unstable planetary boundary layer (PBL) and the surface fluxes of heat and water vapour, a simple "slab" model of PBL growth was tested (Zilitinkevitch parameterization, Tenneckes and Driedonks, 1981). The primary assumption underlying a "slab" PBL model is perfect mixing (and constant potential temperature) within the PBL. The PBL is capped by a discrete jump in potential temperature and a potential temperature inversion above; it grows by entraining warmer air from above. In the model tested, the rate at which warmer air is entrained from above is controlled by the surface heat flux. The downward heat flux at the PBL top due to the entrainment of warmer air from above is assumed to be a nearly constant fraction of the surface heat flux.

Measurements of PBL height were made with an Echosonde III acoustic sounder during Aug. and Sept., 1987, at the Elora Research Station. The acoustic sounder was located near the ERS weather station; the PBL height measured, however, reflected not only the surface conditions of the weather station grass, but also of the surrounding agricultural region. On average, the acoustic sounder was effective up to heights of 600 m. PBL growth was modelled using inputs of windspeed and sensible heat flux (determined with the Bowen ratio - energy balance method) above a nearby maize field (a crop typical of the region), or inputs of windspeed and sensible heat flux (inferred from the temperature gradient between 2 and 8 m) at the weather station. The strength of the potential temperature inversion above the PBL was calculated from 08:00 EST radiosonde data from Buffalo, N.Y., Sault St. Marie, Ont., and Flint, Mich. Days were chosen for modelling which were relatively cloud free before noon, and in which no frontal activity was present.

Sensitivity analysis showed the modelled rate of PBL growth to be very sensitive at all times to the strength of the potential temperature inversion capping the PBL, and moderately sensitive at all times to the surface heat flux. The initial value chosen for the potential temperature jump at the top of the PBL influenced the PBL growth rate early in the day but not later. This value was impossible to infer from the radiosonde data, and was always set initially to 1°C.

Measured and modelled PBL height are shown for three typical days in Fig. 1. In general, modelled PBL height agreed well with measured height, or underestimated it. The lack of agreement on certain days may be due to our inability to adequately specify the initial and boundary conditions of the model, especially the local strength of the inversion capping the PBL (we used a gross regional value). Or it may be due to the invalidity of the assumption that the rate at which heat enters the PBL from above as warmer is entrained is at all times a constant fraction of the surface heat flux.

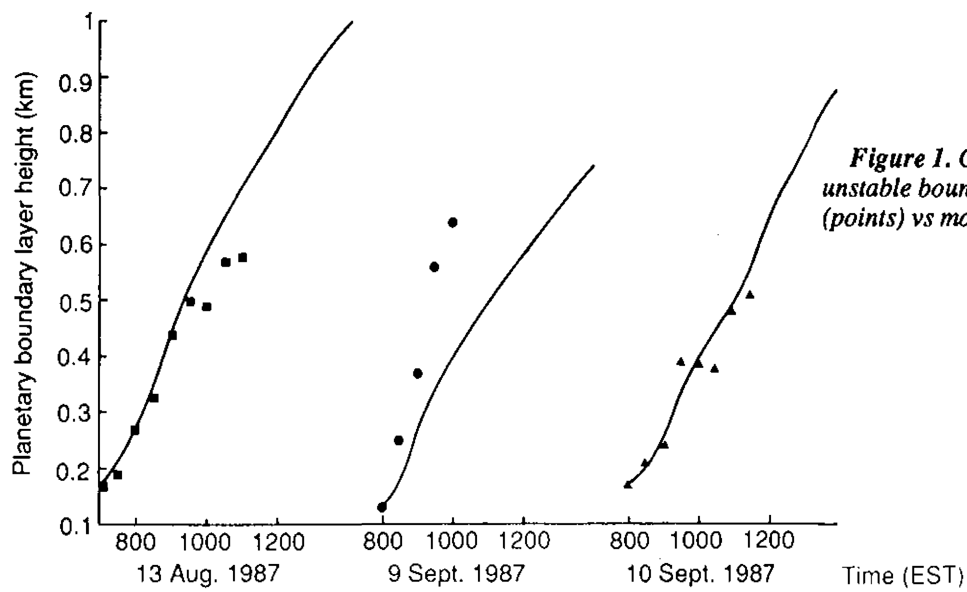

Figure 1. *Growth of the daytime unstable boundary layer: measured (points) vs modelled (lines)*

A model of PBL growth provides the ability to investigate how feedbacks between the surface and the atmosphere influence the surface energy balance. One application is a more rational prediction of the impact of elevated atmospheric carbon dioxide concentrations on crop water use. Many controlled environment and open-top field chamber studies have reported a dramatic increase in crop water-use-efficiency in response to elevated atmospheric carbon dioxide concentrations, due in part to reduced evapotranspiration. But a weakness in these studies is the failure to consider evapotranspiration (ET) at the regional scale. Because PBL growth interacts with the surface energy balance (and ET!), reduced ET at elevated CO_2 may increase the atmospheric evaporative demand and buffer the reduction in ET. To achieve a better understanding of the impact of elevated atmospheric CO_2 on crop water use, it will be necessary to integrate the present knowledge of the influence of elevated CO_2 on agricultural crops with a knowledge of the interaction between the planetary boundary layer and surface evapotranspiration.

TALC AS A PRODUCT OF WEATHERING

D. Crabtree and W. Chesworth

Most weathering systems on the land surface of the earth as evidenced by the gravitational waters draining soils and natural ground, river and lake waters, would be in equilibrium with kaolinite, if in fact, an equilibrium were reached. For this reason, the "kaolinite window" (Sposito, pers. comm.) is often a convenient means of examining the chemistry of soil. However, there are a number of situations in the weathering regime where the kaolinite window is inappropriate. Generally, these will be situations in which the composition of any aqueous phase present is higher than average in such cations as Ca^{2+}, Mg^{2+}, K^+ and Na^+. We could expect such a state of affairs where the circulation of the aqueous phase was poor, or where the climatic regime had evaporation dominating over precipitation. Examples of such environments would include arid and semi-arid regions of the globe, landscape depressions that collect drainage waters, fine capillary pores in soil, and the microscopic systems of the mineral water interface. All of these could produce an aqueous phase, out of equilibrium with kaolinite.

Consider for example the System MgO-SiO_2-Al_2O_3-H_2O. Fig. 1 shows the phases in equilibrium with solution at 25°C and 100 kpa. The labelled surfaces define an irregular box that encloses all possible equilibrium solutions. The figure indicates that most natural waters, which will have log $(Mg^{2+})/(H^+)^2$ much lower than 13, will be in equilibrium with gibbsite, kaolinite or quartz, or combinations of these three. The quartz-solution equilibrium is not favored kinetically and its place is normally taken up by a metastable extension of the kaolinite surface. Gibbsite can be found in areas of high pH or very rapid drainage, but the fact remains that the kaolinite window will usually give the best perspective on the mineral chemistry of a weathering system.

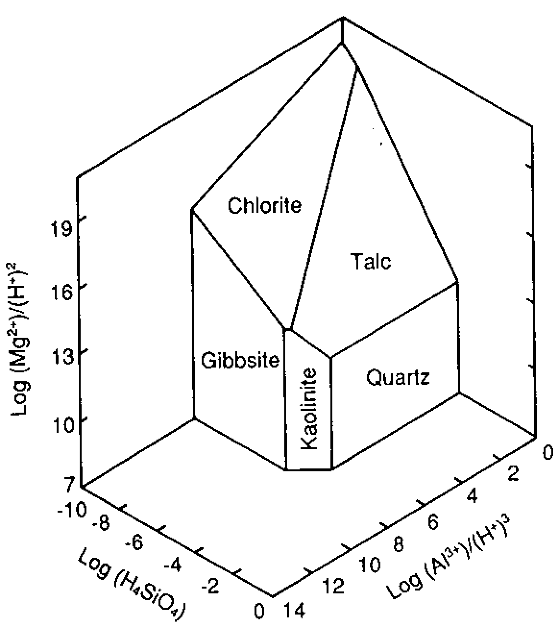

***Figure 1.** The system MgO-SiO_2-Al_2O_3-H_2O at 25°C and 100 kPa. Extent of the field of aqueous solution.*

However the diagram also shows that in those systems already mentioned, where dissolved Mg^{2+} can be expected to be high, and H^+ low, it might be possible to stabilize talc and even chlorite. In fact talc has been reported by several workers as a possible weathering product of ultrabasic rocks in several parts of the globe. Rosa Calvo and co-workers at the University of Santiago, Spain, for example report a weathered assemblage from Galacia containing talc, vermiculite, serpentine and goethite. But in such assemblages it is not really clear which minerals are produced by weathering and which are produced by low grade metamorphism.

As previously mentioned, the micro-environment at the mineral solution interface is a weathering system in which a phase such as talc might be expected. Here, the aqueous phase is essentially stagnant and its composition has the chance to saturate with respect to phases more soluble than kaolinite. Pyroxene surfaces could be a particularly good hunting ground for talc, since the lattice dimensions of pyroxenes and talc are very similar and the pertinent chemical components are present. Numerous workers (Eggleton and Boland, 1982; Veblen and Buseck, 1980 and 1981) have successfully used T.E.M. to demonstrate the presence of a "metastable" 2:1 trioctahedral layer silicate in altered pyroxenes.

Eggleton (1986) proposed that early forming talc produces such good structural continuity with pyroxenes that diffusion avenues along which weathering solutions pass are restricted to a few angstroms. As a result saturation of the solution with respect to a phase such as talc becomes possible if the solution is not flushed from the mineral interface.

Some indications that our reasoning is sound, comes from a study of the weathering of Tukuyu basalt from southern Tanzania. We have sampled a sequence of weathered surfaces on a columnar variety of this basalt and analysed individual phases by electron microprobe and X.R.D. The mineralogy of the fresh rock and the altered zone is characterized by the sequence shown in Table 1.

Table 1

Clinopyroxene	Goethite
Plagioclase	Kaolinite
Titanomagnetite	Titanomagnetite
Olivine	
(fresh rock)	(most weathered zone)

X.R.D. has revealed the possible presence of talc within the first zone of alteration, and it is proposed here that clinopyroxene (titanaugite) is a likely precursor to this 2:1 layer silicate. In the outer alteration zones of the sequence talc is certainly absent, probably because increased weathering favors a loss of volume and therefore more extensive flushing of the system. Under these conditions talc would become unstable and give way to an alternative secondary phase or phases. Confirmatory work on this possibility still needs to be done since it is based on an identification of talc that requires an independent confirmation.

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Velben,D.R. and Buseck,P.R.1980. Microstructures and reaction mechanisms in biopyriboles. Amer. Mineral. 65,599-623.

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SEM AND MICROPROBE STUDY OF MINERAL GRAINS FROM PODZOLIC SOILS

C. Cruickshank and L.J. Evans

Podzolic soils occupy approximately 22% of Canada's land surface. They are characterized by an eluviated Ae horizon and an illuviated Bf horizon. The mineralogy of the Ae horizon is dominated by quartz and feldspar with few phyllosilicates, while the Bf horizon is enriched in accumulated products, such as poorly-ordered aluminosilicates and iron oxyhydroxides. The exact mechanisms by which Fe and Al are transported from the A to the B horizons and subsequently precipitated within the soil profile are unknown. Presently there are three theories under consideration - the first suggests that the metals move as inorganic sols, the second that they move as organic complexes and the third is a combination of both. The nature of the research reported here has been to investigate the nature and morphology of the mineralogy of some podzolic soils from northeastern Ontario.

The morphology of the minerals in the Ae and Bf horizons of these podzolic soils was studied using optical and scanning electron microscopy. Their chemistry was investigated using an energy dispersive system attached to the scanning electron microscope (SEM), and a microprobe. Previous work performed on northeastern podzols has shown that as much as 50% of the feldspars in the Ae horizons were weathered and that the ease of weathering trends from calcic feldspar to microcline to albite. Organic acids are believed to be the effective agents in mineral dissolution in podzolic soils.

Because of its high resolution, the SEM is an ideal instrument for the investigation of sub-micron features, such as those found as a result of mineral weathering. A study of intact peds from the Ae horizon indicated that the feldspar weathering trend previously mentioned is also applicable to these soils. Although quantification of minerals is not possible, every horizon studied appeared to be dominated by albite. The feldspars examined displayed a wide variety of etching features, the most intense of which are shown in Figure 1. These prismatic etch pits are quantitatively the most destructive type of etching - the mineral will achieve in time a honeycomb-like appearance and will easily disintegrate during freeze-thaw cycles due to its fragility. Organic acids do not appear to attack the entire mineral surface, but rather etch the 'weak links' in the crystallographic make up of the mineral. These weak links are the unsatisfied charges located at edges or corners and it is at these locations that the chemical bonds within the structure are most vulnerable to dissolution. In some studied feldspars it was possible to locate the c-axis simply by following the parallel trend of the prismatic etch pits.

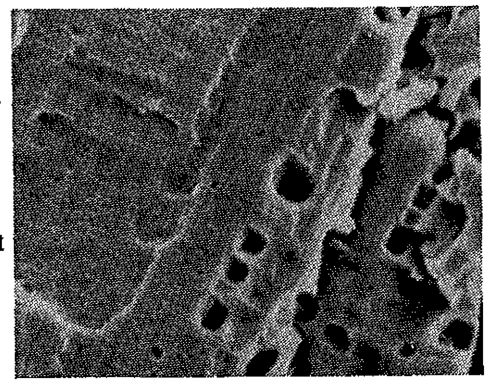


Figure 1. *Prismatic etch pits in a Ca-rich feldspar.*

Observations under the SEM on the morphology of mineral grains from the Bf horizon revealed dramatic differences from that of the Ae horizon. Mineral grains were thickly coated with amorphous materials having a variety of chemical compositions. Energy dispersive X-ray analysis indicated an order of abundance of chemical elements within the coatings to be : Si>Al and/or Fe>Mg>Ca>K>Na = Ti. The precipitation of amorphous products should occur initially on the most reactive sites, which are generally organic material. Fungal hyphae (Figure 2) appear to provide the most receptive surfaces, but as the amorphous material becomes thicker, the mineral grains also become coated. Examination of grains from which amorphous coatings have been dislodged by sonification revealed that etching was occurring below the precipitated material (Figure 3). Hence, contrary to one popular school of thought, the amorphous coatings do not appear to protect the mineral grains from dissolution by acids, as they were found to be too patchy, discontinuous and did not prevent diffusion of weathering agents into the mineral grain.

The chemical composition of the coatings was also investigated by examining impregnated thin sections with a microprobe. Lateral scans through a coated grain indicated that Fe-rich and Al-rich coatings are precipitated collaterally. This difference in spatial distribution of Fe and Al suggests either different times or mechanisms of precipitation. More information is required on reactions and translocations within the soil profile before these mechanisms can be fully understood.

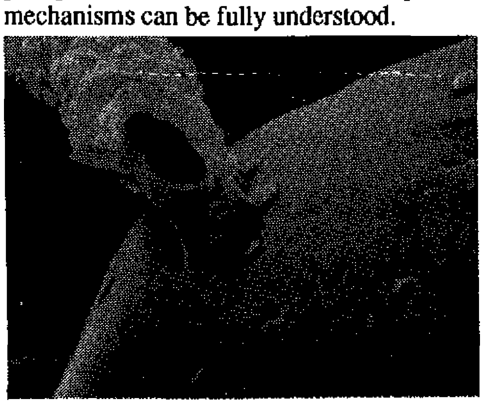
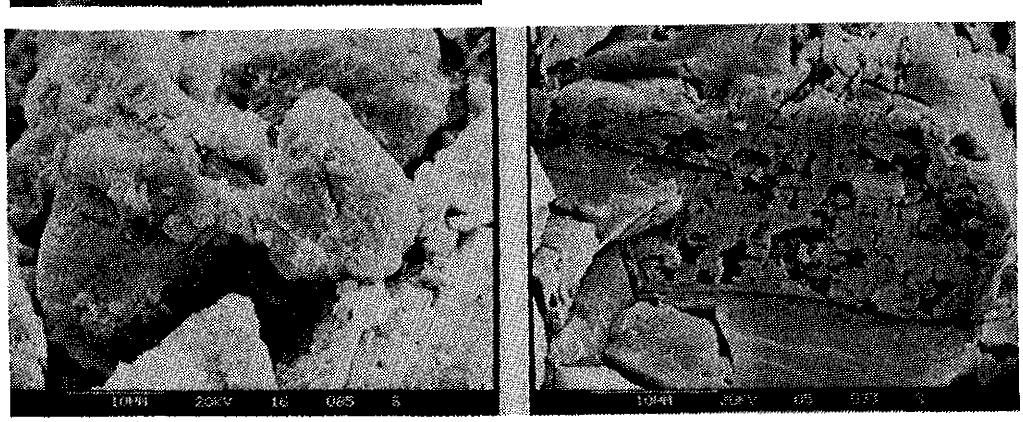


Figure 2. *Thickly coated fungal hyphae attached to a quartz grain.*



UNSONIFIED SONIFIED

Figure 3. *Na-rich feldspar - before and after sonification.*

FIELD MEASUREMENTS OF SOIL HYDRAULIC PROPERTIES - THE GUELPH PERMEAMETER AND INFILTROMETER

D.E. Elrick, N. Baumgartner, W.D. Reynolds and K.A. Tan

Two important parameters controlling water movement in soils are the field-saturated hydraulic conductivity, K, and the matric flux potential, ∅ (a term which incorporates the contribution to flow of the unsaturated hydraulic conductivity). In addition, simplifying assumptions can be applied to the above parameters in order to approximate the soil sorptivity, S, and the "∝" parameter of an assumed exponential form of the unsaturated hydraulic conductivity-soil water pressure head relationship.

The above hydraulic properties can be obtained from field measurements of the steady intake rate of water from a cylindrical test hole located above the water table. From a practical point-of-view, it is important to know approximately how long it should take to attain some given percentage of steady flow for a range of soil structural/textural conditions. The results of a simulated flow suggest that times are short enough in highly permeable soils to fall to approximately 110% of steady flow within 30 min or less; in slowly permeable soils about 6 hours or more may be required.

The original analysis of data obtained from the Guelph Permeameter was based on steady intake rate measurements, Q_1 and Q_2, at two ponded heights of water in which the soil volumes being sampled at these two heights were assumed to be homogeneous. Factors which can contribute to errors in the determination of the steady flow rates are: (1) non-attainment of "true" steady flow which can given rise to an overestimation of Q_1 and Q_2 by 10% or more in permeable sandy soils and perhaps by 50% or more in slowly permeable unstructured clay soils and (2) errors in the experimental measurements of Q_1 and Q_2 because of air bubble size and reading errors in the Mariotte-based Guelph Permeameter. It is therefore possible to obtain experimental Q_1 and Q_2 data in homogeneous soils that differ substantially from the theoretical Q_1 and Q_2 values. In soils in which the hydraulic properties are substantially different in the two sampling volumes, then the values for Q_1 and Q_2 which are measured will be representative of the soil properties in these different sampling volumes.

The result of applying an analysis based on homogeneous soil conditions to data obtained by the above procedure has led to some Q_1, Q_2 data sets giving negative values of either K or ∅. In general, fewer negative values have been reported in relatively uniform sandy soils and a higher percentage, at times 50%, in slowly permeable clay soils.

An analysis is being developed which is based on the assumption of nonhomogeneous soil properties in the Q_1 and Q_2 sampling volumes of either the Permeameter or Infiltrometer. Preliminary results using this procedure gives a consistent set of K and ∅ data that best approximate the existing conditions.

VA-MYCORRHIZA AND THE SOIL-DISTURBANCE-INDUCED REDUCTION OF NUTRIENT ABSORPTION IN MAIZE

G.L. Fairchild and M.H. Miller

Phosphorus absorption by maize seedlings from soil in a long-term zero-till system has been found to be greater than that from the same soil after disturbance (O'Halloran, Miller and Arnold, 1986). This was due, at least in part, to greater mycorrhizal infection in the undisturbed soil (Evans and Miller, 1987).

The experiments of O'Halloran, Miller and Arnold (1986) and Evans and Miller (1987) were conducted on soil taken from plots that had been in zero-till for at least nine years. This report contains the results of a growth room experiment conducted to determine how quickly the soil disturbance effect would develop if an initially disturbed soil were allowed to remain undisturbed. The experiment was also designed to further test the hypothesis that the effect of soil disturbance on P absorption is a consequence of an effect on mycorrhizal infection.

To investigate the effect of soil disturbance on mycorrhizal infection and P absorption in maize, Conestogo silt loam soil contained in 20-cm (diameter) plastic cylinders was subjected to a pretreatment cycle followed by three treatment cycles in a growth room. In each cycle maize was grown for three weeks. At the beginning of the pretreatment cycle, all soil was disturbed. At the beginning of each treatment cycle, soil in half the cylinders was disturbed while the soil in the remaining half of the cylinders was left undisturbed.

Over the three growth cycles, major increases were observed in mycorrhizal infection in the plants in the undisturbed soil (Fig. 1). These differences were evident 14 days after planting in the third growth cycle (Fig. 2).

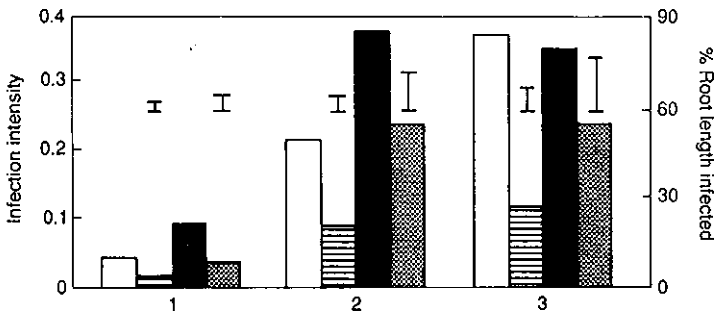


Figure 1. The effect of soil disturbance on mycorrhizal infection in the top 6 cm of soil after 21 days of plant growth.

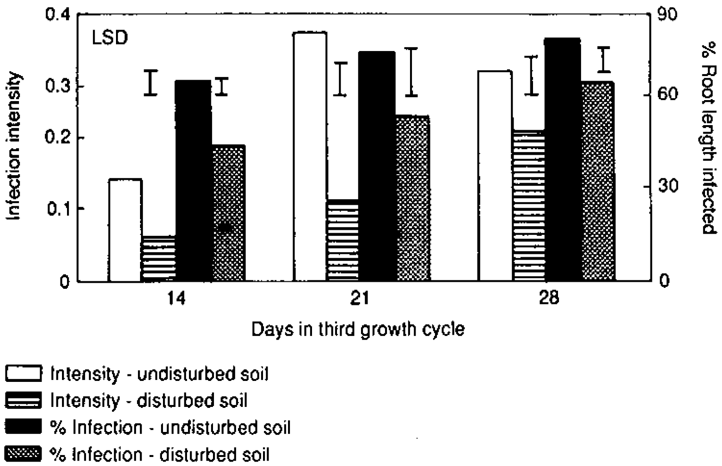


Figure 2. The effect of soil disturbance on mycorrhizal infection in the top 6 cm of soil after 14, 21 and 28 days of plant growth in the thrid growth cycle.

A significant increase in P absorption occurred in the first growth cycle on undisturbed soil and even greater increases occurred after the second and third growth cycles (Fig. 3). Absorption of P between 14 and 21 days of the third growth cycle in the undisturbed soil was 10 times larger than in the disturbed soil (Fig. 4).

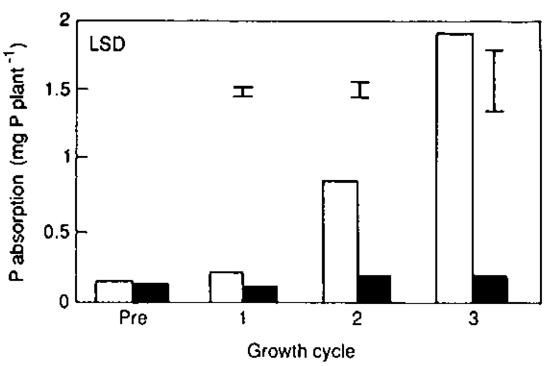


Figure 3. The effect of soil disturbance on P absorption from soil during the 21-day growth period.

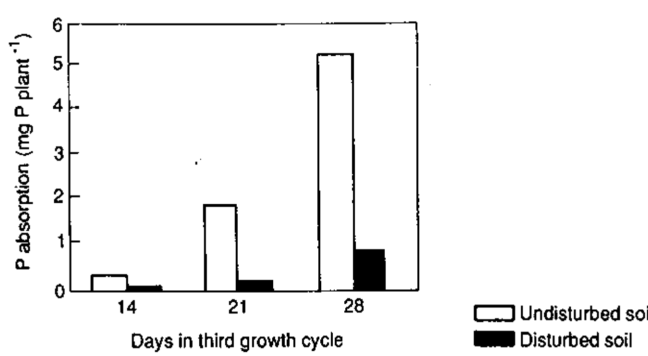


Figure 4. The effect of soil disturbance on P absorption after 14,21 and 28 days in the third growth cycle.

At 21 days in the third growth cycle, plants grown in the undisturbed soil had almost twice the dry weight and had higher plant tissue concentrations of N, Mg, Cu and Zn than did plants grown in the disturbed soil. Absorption of N, Mg, Cu and Zn was more than three times larger. In the third growth cycle, as early as 14 days after planting, mycorrhizal infection intensity and plant tissue concentrations of N, P, Mg and Zn were greater in the undisturbed soil.

The results show that there was a concurrent and rapid increase in mycorrhizal infection and P absorption by maize over three growth cycles when an initially disturbed soil was left undisturbed. This rapid concurrent development, particularly starting from an initially disturbed soil, provides good evidence of a cause-effect relationship between soil disturbance and a reduction in mycorrhizal infection and P absorption by maize.

The magnitude of the soil-disturbance-induced reduction in mycorrhizal infection and P absorption suggests that mycorrhizae may play a more important role in P nutrition in crop production systems than was previously thought. In the undisturbed soil conditions in this experiment, maize seedlings can derive a large nutritional benefit from mycorrhizal infection as early as 14 days after planting (Figs. 2 and 4). Soil tillage, in comparison to zero-tillage practice, may result in a reduction in mycorrhizal infection and P absorption in seedling maize. The effect of soil disturbance was evident even in the first growth cycle (Figs. 1 and 3) indicating that the benefit of non-disturbance develops quickly and is not reliant on long-term changes in soil characteristics. This suggests that it may be possible to capitalize on this phenomenon in crop production systems.

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PARTIAL INHIBITION OF FERMENTATION AND DISSIMILATORY NITRATE REDUCTION TO AMMONIUM BY ACETYLENE AND THE IMPLICATIONS FOR DENITRIFICATION ASSAYS

D. Flather and E. G. Beauchamp

Acetylene is known to affect several biological processes occurring in soil. Nitrification, methanogenesis, and nitrous oxide reduction to dinitrogen are all inhibited in the presence of acetylene. The latter inhibition has permitted accurate quantification of the denitrification potential of soils in the laboratory. However, in anaerobic soil, where a readily utilizable carbon source is available, fermentative bacteria will also compete with the denitrifiers for nitrate for use in the energy conserving process of dissimilatory nitrate reduction to ammonium. The effect of acetylene in such a system is the subject of further research.

Our research to date has shown that glucose-amended anaerobic soil, in the presence of 10 kPa of acetylene, produced significantly ($P<0.05$) less CO_2 and fermentation products (quantified as total volatile fatty acids produced) than soil with only He in the headspace after 96 h incubation. Similarly, the extent of NH_4^+ production from NO_3^- in the absence of acetylene was significantly greater after 24h than identically treated soil with 10kPa of acetylene in the headspace. The implication of this research is that denitrification rates are overestimated using the acetylene blockage technique because a viable population of microorganisms that would be competetive for nitrate is inhibited in the presence of acetylene. Hence, the amount of available nitrate to denitrifiers is effectively increased.

ULTRASONIC DISPERSION OF AGGREGATES: THE NATURE AND DISTRIBUTION OF ORGANIC MATTER IN AGGREGATES

E.G. Gregorich, R.G. Kachanoski and R.P. Voroney.

This study was undertaken to examine the arrangement of organic matter within a soil aggregate and to determine the nature of the organic matter involved in bonding inorganic primary particles into aggregates.

Aggregates (1-2mm) from a soil under continuous corn management were subjected to a mild shaking treatment and various levels of ultrasonic energy ranging from 100 to 1500 J ml^{-1} water to determine the degree of aggregate disruption and dispersion. The results indicated that most of the breakdown of sand size aggregates occurred between energy levels of 300 and 500 J ml^{-1}). Ultrasonic energy levels of 500 J ml^{-1} or greater were more effective than using 20% hydrogen peroxide plus 16 hours of shaking in dispersing sand size microaggregates.

After the application of a specific ultrasonic energy level or mild shaking the samples were separated into sand, silt and clay size fractions by gravity sedimentation. It is important to note that primary particles, as well as microaggregates, would have been included in a particular size fraction at lower energy levels. The size fractions were dried at 40°C and mixed with washed sand; a mineral nutrient solution and a fresh soil inoculum were added, and the samples were then incubated for 20 days at 24°C. CO_2 production was measured at regular intervals during this period.

On a whole soil basis, dispersion treatments 500 J ml^{-1} or greater had more total C mineralized in the 0-2 day period than dispersion energy levels 300 J ml^{-1} or less (Fig. 1). In addition, all of the size fractions showed a large increase in the amount of C mineralized between 300 and 500 J ml^{-1}. This is the energy increment at which the breakdown of microaggregates occurred. These results suggest that organic matter which had previously been physically protected was exposed with the breakdown of microaggregates. The amount of C mineralized during the 6-10 day period (Fig. 2) in the clay size fraction of 500 J ml^{-1} treatment decreased substantially from that mineralized in the first 2 days (from 40.9 mg C kg^{-1} whole soil during the 0-2 day period to 9.7 mg C kg^{-1} whole soil in the 6-10 period). This shows that the organic matter which had been sequestered within microaggregates and subsequently exposed by the breakdown of microaggregates and then had accumulated in the clay size fraction was easily decomposed and metabolized by soil microorganisms. More than 70% of the C mineralized in the clay size fraction in 20 days was mineralized in the first 5 days.

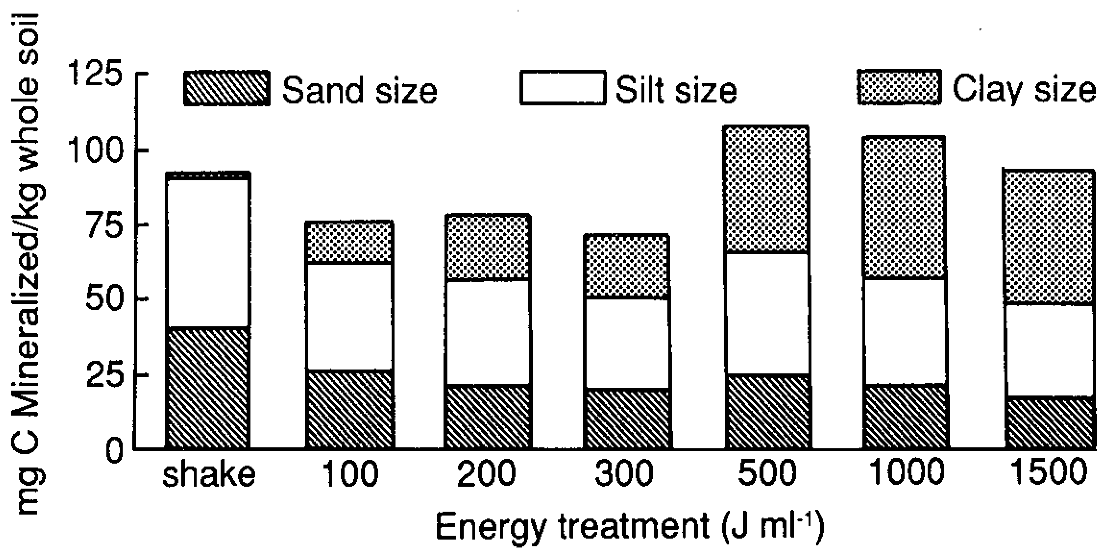

Figure 1. The amount of C mineralized in the 0-2 day period of incubation in the sand, silt, and clay size fractions.

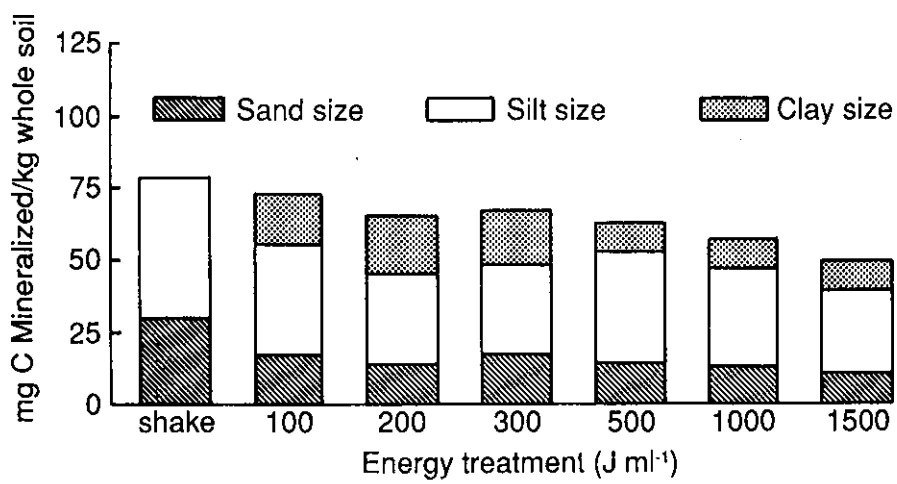

Figure 2. The amount of C mineralized in the 6-10 day period of incubation in the sand silt, and clay size fraction with different dispersion energy treatments.

The relative pool of potentially mineralizable carbon, C_r, in a size fraction at a particular energy level and the corresponding mineralization rate coefficient, k, was estimated by a first order equation:

$$C_t = C_r (1 - e^{-kt})$$

where C_t is the cumulative C mineralized in time, t. The estimated C_r of the sand size fraction increased with dispersion energy indicating that the physical dispersion of aggregates by ultrasound increased the relative pool of the potentially mineralizable C (Table 1). The k estimates of the sand size fraction are similar, ranging from 0.096

to 0.141, and are slightly higher for samples with complete dispersion. This suggests that the organic matter which was involved in the bonding of inorganic primary particles into sand size microaggregates and which remained in the sand size fraction after the breakdown of microaggregates was similar to that organic matter located on the exterior of microaggregates. The incubation period required to mineralize one-half of the potentially mineralizable C, $t^{1/2}$, (from the formula $t^{1/2} = \ln 2/k$) is shown in Table 1 col. 4. The half-lives for the sand size fraction were also similar and do not vary greatly with increased dispersion energy.

Excluding the shake treatment, the estimated C_r for the clay size fractions decreased with increased dispersion energy and showed a sharp drop with the disruption of microaggregates, between 300 and 500 J ml^{-1}. Thus, with dispersion and the release of organic matter from microaggregates, the relative pool of potentially mineralizable C decreased. In addition, the estimates of k increased sharply with the breakdown of microaggregates. These data, along with the half-lives, indicate that while the relative pool of potentially mineralizable C is smaller after complete dispersion, the material itself is relatively more easily metabolized and more labile.

C_r is an estimate of the relative pool of potentially mineralizable C per unit weight carbon. An estimate, in absolute terms (per unit weight whole soil), of the pool of potentially mineralizable carbon, C_a, was obtained by multiplying the C_r by the amount of C in the size fraction and the amount of sand or clay recovered at a specific dispersion energy. The estimated C_a in the sand size fraction does not follow the consistent trend found for the C_r. This may be the result of material being lost with increased dispersion energy while other material, previously sequestered, is made available. The estimated C_a in the clay size fraction increases up to the energy increment of microaggregate dispersion and then decreases. Since it is physically impossible to decrease the absolute pool (the dispersion treatments were continually moving material into the clay size fraction), the first order model is probably not a good model for describing the mineralization process at dispersion energy levels 500 J ml^{-1} or greater. A two component model may be more appropriate for these energy levels.

The amount of C mineralized before and after disruption of microaggregates in the sand and clay size fractions is shown in Fig. 3 and 4, respectively. The organic matter which remained in the sand size fraction after the disruption of microaggregates was relatively more labile than that organic matter located on the exterior of microaggregates. The organic matter in the clay size fraction after complete dispersion contained the same material as that prior to the breakdown of microaggregates plus previously sequestered material. Thus any differences in the nature of the organic matter are a result of the sequestered material. If the sequestered material was composed of only labile material, it would be expected that after the disruption of microaggregates more C would be mineralized during the incubation in the clay size fraction. If the sequestered material was very resistant material, less C would be mineralized. Fig. 4 shows that some labile organic matter was released with the disruption of microaggregates but it appears that a large amount of resistant material was also released and caused the C mineralized during the incubation to be less in samples with complete disruption of microaggregates.

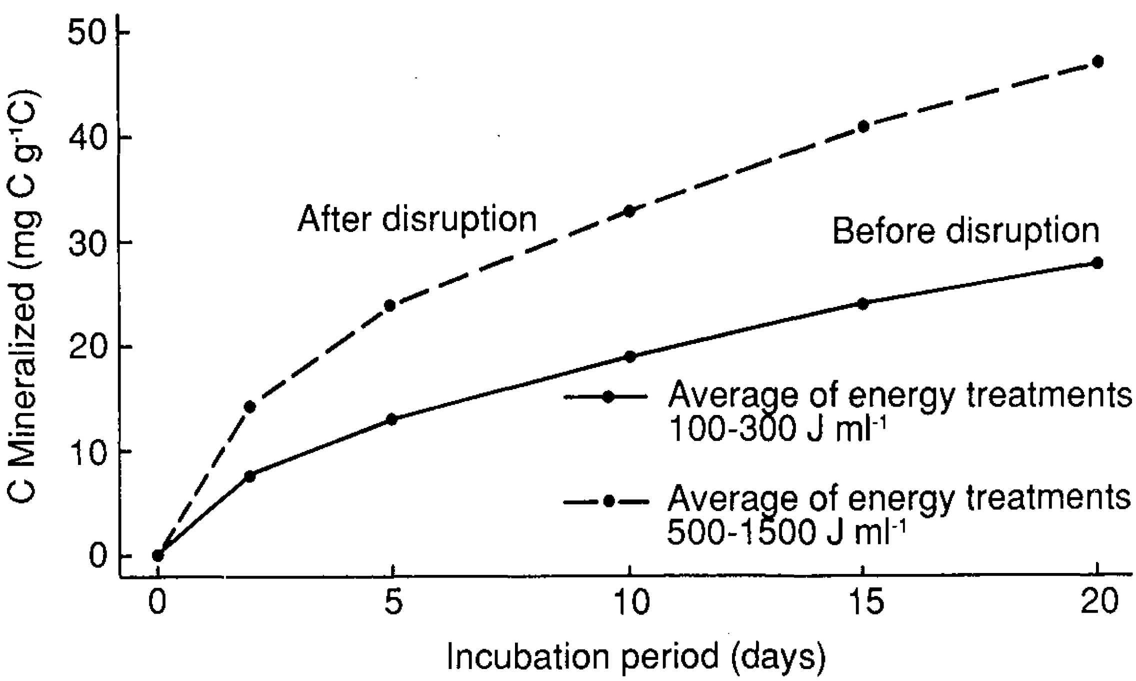

Figure 3. C mineralization in the sand size fraction before and after the disruption of microaggregates.

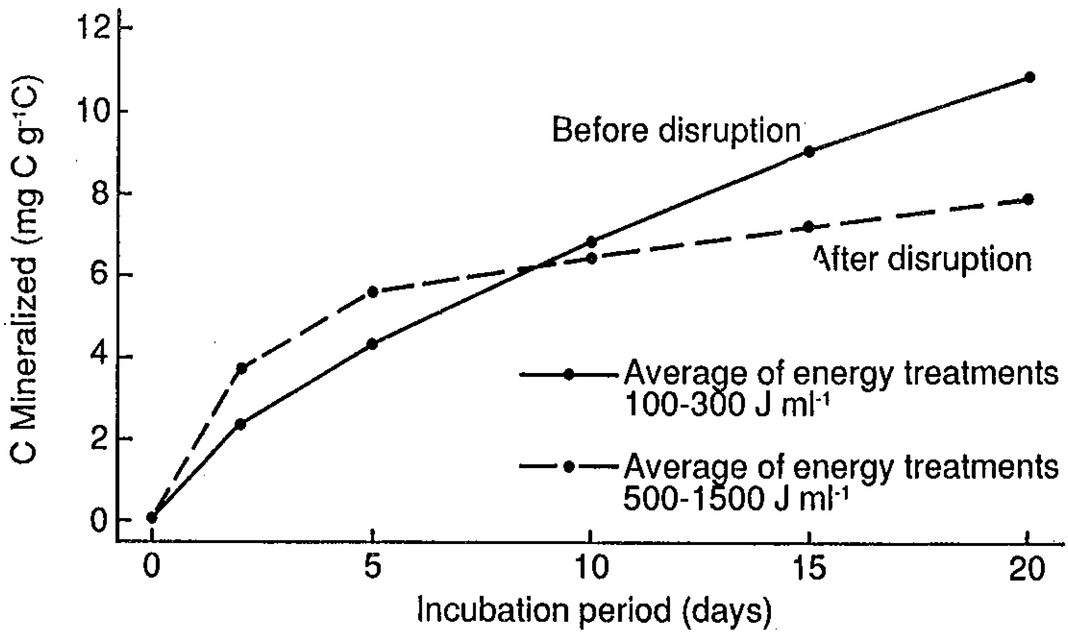

Figure 4. C mineralization in the clay size fraction before and after the disruption of microaggregates.

Table 1. Estimates of relative soil C mineralization potential, C_r (mg C g^{-1} C), specific mineralization rate constant, k (day^{-1}), half-lives for C mineralization, $t_{1/2}$ (days) and soil C mineralization potential in absolute terms, Ca, (mg C g^{-1} whole soil).

Dispersion energy	C_r	k	$t_{1/2}$	r^2	C_a
	Sand size fraction				
shake	23.6	0.116	5.8	0.97	114
100	26.9	0.121	5.8	0.96	86
200	26.1	0.120	5.8	0.97	73
300	38.2	0.096	6.9	0.99	89
500	43.4	0.141	5.0	0.97	76
1000	51.4	0.128	5.3	0.97	71
1500	51.0	0.127	5.3	0.97	58
	Clay size fraction				
shake	2.5	0.080	8.7	0.62	5
100	15.5	0.060	11.6	0.99	95
200	14.7	0.074	9.4	0.99	114
300	12.8	0.075	9.2	0.98	114
500	8.0	0.291	2.4	0.93	83
1000	7.7	0.317	2.2	0.92	92
1500	6.4	0.302	2.3	0.93	88

PHENOLIC ACID RETENTION BY AMORPHOUS IRON HYDROXIDE

F. Jensen and L.J. Evans

The genesis of podzolic soils is thought to involve, at least in part, the formation, translocation and immobilization of organo-metallic complexes. As a result podzolic soils are characterized by a quartz-rich horizon overlying a brown to dark brown lower horizon which contains, in addition to crystalline phases, amorphous combinations of organic matter, Al and Fe. Of the amorphous constituents in the podzolic B horizon, ferric hydroxide has been reported to be chemically reactive toward phenolic acids.

The primary objectives of the study were (i) to test the applicability of various empirical equations for summarizing phenolic acid retention, (ii) to calculate the maximum amount of phenolic acid likely to be retained by an amorphous Fe compound at an initial pH of 3.5 and (iii) to suggest some possible mechanisms for phenolic acid retention under the experimental conditions used. Amorphous ferric hydroxide was prepared by the addition of a 13% NH_3 solution to a 0.01 M $Fe(NO_3)_3$ solution. Analysis of the prepared material by x-ray diffraction showed no diffraction lines confirming it as a noncrystalline Fe compound.

The amount of each phenolic acid (mmol/kg) retained by the amorphous Fe hydroxide was calculated as the difference between the initial and final solution concentrations using 0.010 M $NaNO_3$ as the indifferent electrolyte (pH = 3.5) after 1 hour of equilibration. The pH of final supernatant solutions was measured and the acid content was determined colorimetrically. The maximum amount of the organic acids retained by the amorphous Fe hydroxide was calculated by fitting the retention data to a series of empirical equations often used to describe retention data. The following equations from the literature were examined:

Langmuir
$$q(c) = \frac{Bac}{1 + ac} \qquad (1)$$

Gunary
$$q(c) = \frac{1}{B + a/c + d/c^{1/2}} \qquad (2)$$

Dubinin Radushkevich
$$q(c) = a\exp(-Be^2) \qquad (3)$$

Van Bemmelen-Freundlich
$$q(c) = ac^B \qquad (4)$$

Tempkin
$$q(c) = a_1 \ln(a_2 c) \qquad (5)$$

Two-surface Langmuir
$$q(c) = \frac{a_1 B_1 c}{1 + a_1 c} + \frac{a_2 B_2 c}{1 + a_2 c} \qquad (6)$$

In the above equations, q(c) is the amount of phenolic acid sorbed per unit weight, c is the final concentration of phenolic acid in solution, and a, b, d are coefficients estimated by a nonlinear regression technique. The SAS (Statistical Analysis System) computer program for nonlinear analysis was used for this purpose.

Results indicated that the retention data involving Fe hydroxide could be modelled quite adequately by all the equations examined except for the 2-surface Langmuir (Eqn 6) (Table 1). Retention maxima were calculated for the Langmuir (Eqn 1), Freundlich (Eqn 4), and Dubinin-Radushkevich (Eqn 3) isotherms. The sorption maxima (Table 2) calculated from the Freundlich retention data are lower than those computed using the Langmuir and Dubinin-Radushkevich equations. However, multiple regression analyses showed the three retention maxima to be significantly related ($r^2 = 0.982$) at the 0.01 probability level.

The retention capacity (Table 2) of the phenolic acids followed a decreasing order: salicylic (pka1 = 2.81)> gentisic (pka1 = 2.73) >p-hydroxybenzoic (pka1 = 4.36) >p-coumaric (pka1 unavailable) >protocatechnic (pka1 = 4.14). Under the experimental conditions, final pH values for supernatant solutions of salicylic and gentisic acids fluctuated around an initial pH of 3.5, while the other 5 phenolic acid solutions generally decreased 0.1 to 0.3 pH units (Table 2). In terms of Fe solubility, only trace amounts of Fe were determined by atomic adsorption and no Fe-complexes were detected by visible spectrophotometry.

The original hypothesis of this research was that the acid strength of a phenolic acid would be the primary factor regulating the retention of phenolic acids as ferric hydroxide. This hypothesis was tested by (i) calculating the maximum amount of a phenolic acid likely to be retained by ferric hydroxide (Table 2) and (ii) examining the retention maxima for each phenolic acid in relation to their final pH values and ionization constants (Table 2).

From the above results, it was possible to divide the 7 phenolic acids into 2 broad groups:

(1) Acids with pka 1 <pH 3.5
(2) Acids with pka 2 >pH 3.5

Salicylic and gentisic acids were found to have the highest retention capacities and belong to group 1 acids while the other 5 acids were sorbed in lesser amounts and belong to group 2. According to the final pH values and ionization constants (Table 2), group 2 acids will exist mainly in the unionized form under the experimental conditions while group 1 acids will behave predominantly as ionized monodentate ligands. This suggests that group 2 acids are adsorbed by electrostatic attractions and group 1 acids are most likely adsorbed by a ligand exchange mechanism. Retention capacities for group 2 acids however occur to a much greater extent than would be predicted from their concentrations when compared to other nonspecifically adsorbed anions. Hence the high affinity of the amorphous Fe surface for these incompletely dissociated phenolic acids requires further investigation.

Although the exact nature of the adsorption reactions between ferric hydroxide and phenolic acids of various acidic strengths and chemical structures still remains to be determined, the results of this study point to the active role of amorphous Fe hydroxide in retaining phenolic acids. The reactions of phenolic acids with ferric hydroxide and other soil constituents are of particular interest to the study of podzols since their interactions are most likely involved in the development of two distinct soil chemical compartments; the A and B horizons.

Table 1. Coefficients of Determinations

Equation	Salicylic	Gentisic	p-Hydroxy	p-Coumaric	Vanillic	Gallic	Protocatechuic
Langmuir	0.9989	0.9966	0.9988	0.9994	0.9962	0.9941	0.9898
Freundlich	0.9992	0..9949	0.9949	0.9995	0.9973	0.9954	0.9942
Dubinin-Radushevic	0.9989	0.9979	0.9955	0.9996	0.9971	0.9936	0.9921
Tempkin	0.9980	0.9971	0.9863	0.9993	0.9975	0.9643	0.9867
Gunary	0.9993	0.9911	0.9860	0.9995	0.9859	0.9910	0.9730

Table 2. Retention Maxima

	Final pH	pka 1	Langmuir (mmol/kg)	Dubinin-Radushkevich (mmol/kg)	Freundlich (mmol/kg)
Salicylic	3.54	2.81	1232.05	1238.10	733.04
Gentisic	3.55	2.73	1204.63	1051.88	802.24
p-hydroxy-benzoic	3.31	4.36	920.96	835.84	699.75
p-coumaric	3.35	*	908.40	833.11	638.05
vanillic	3.34	4.51	805.33	745.96	622.79
gallic	3.34	4.15	768.36	701.13	571.64
protocatechuic	3.34	4.14	688.89	674.96	588.27

* Data unavailable

PODZOLS IN SPAIN

F. Macias, M. Fernandez and W. Chesworth

The podzols in Spain are mainly where it rains. Figure 1 shows the localities of well described podzols in Spain in relation to the 800 mm isohyet. The northwestern cluster is principally in the provinces of Galicia and Asturias. The following account relates to them.

The geochemical separations between the components SiO_2, Al_2O_3 and Fe_2O_3 is shown in Figure 2, the direction and extent of which are controlled by pH, pe and the presence of organic acids and ligands (Chesworth and Macias, 1985, Amer. J. Sci. 285: 128-146). In general, the Ae horizons on the one hand, and the Bh and Bs horizons on the other, show complementarity with respect to parent material composition. However, unlike the situation for boreal podzols in Northern Ontario, the complementarity is not a linear one. This may be due to lack of homogeneity in the parent material or simply to long term variations in the ambient conditions of pedogenesis.

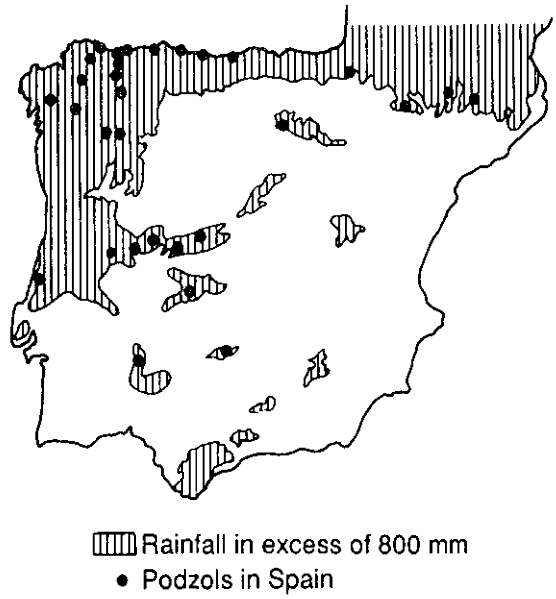

Figure 1. Location of podzolic soils in the Iberian Peninsula.

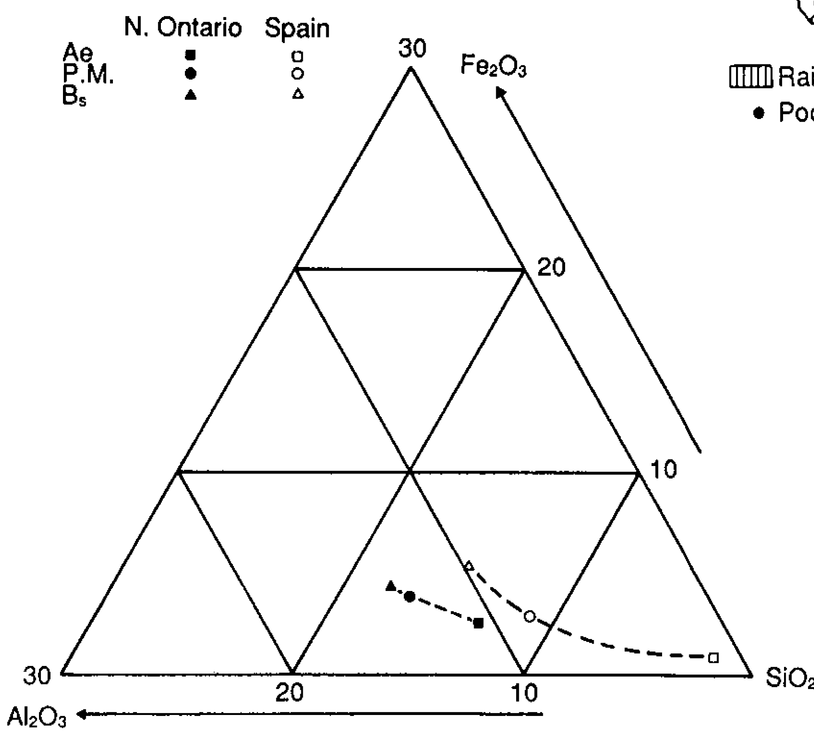

Figure 2. Podzolic trend in Spanish podzol (Asturias) compared with trend in boreal podzol from the Lake Nipigon region.

Soil solutions extracted from these soils by displacement have compositions that fall for the most part within the field of stability of kaolinite at 25°C and 100 kPa. If however we consider that the temperature in NW Spain varies roughly between 0°C in winter and 25°C in summer, it is reasonable to expect that for part of the year, soil waters from the A horizon lie mostly in the field of unsaturated solutions (Fig. 3). In addition, many of the measured soil water compositions fall within fields where phases such as halloysite, imogolite, gibbsite, beidellite and allophane could form metastably. However, clustering of soil water compositions around the quartz-kaolinite line in Fig. 4 indicate the possibility that these two phases are active in controlling solution composition.

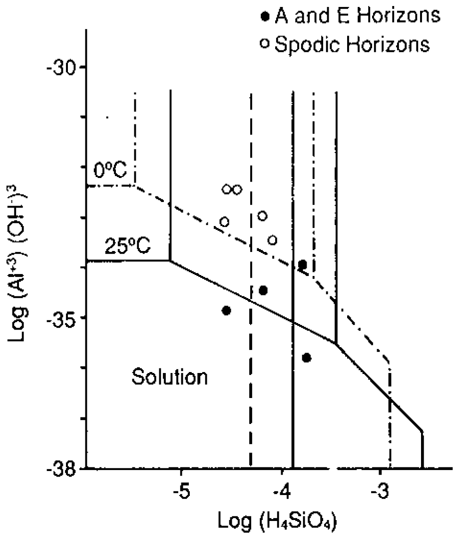

Figure 3. *Effect of temperature on stability field in the system SiO_2-AlO_2-H_2O*

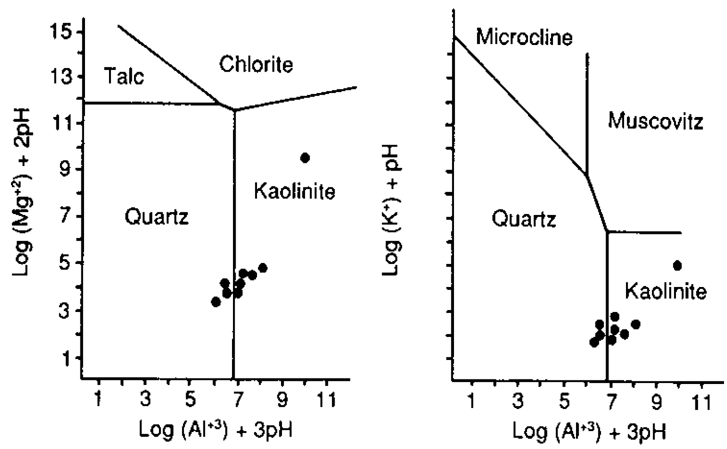

Figure 4. *Soil water compositions illustrating clustering around the quartz-kaolinite univariant boundary.*

PERMIAN COAL MEASURES OF THE PARANA' BASIN, BRAZIL

I. P. Martini

The objective of this research is to perform a comparative sedimentological analysis between the Quaternary peatlands and associated fluvial and paralic environments of the Northern Hemisphere, and of Ontario in particular, and the early Permian Coal Measures of the Parana' Basin in Brazil.

In the past thirty years, tremendous advances have been made in sedimentology, expecially in the understanding of ocean floors, marine shelves, and coarse grained braided rivers. The focus in the last few years has been on the new frontiers of polar and modern glacial sedimentation. We at Guelph can contribute significantly to one facet of the new sedimentology by analyzing sediments and soils of subarctic and cold-temperate regions.

One major feature of such recent cold regions is the development of extensive, thick peatlands. The peatlands are dominated by Sphagnum mosses in both fens and bogs. These environments lead to specific peat sequences and characteristic features in the underlying mineral substratum, for instance, the relatively limited development of rooted zones. Some of these features are encountered, albeit modified, in the lowermost Permian coals of Gondwanaland (ancient southern hemisphere). Fens certainly existed at that time. Recent studies indicate that mosses existed also although perhaps not as widespread. We may wish to look closely at these organic layers and establish whether or not bog-like conditions, or equivalent ombrotrophic raised forests developed during the Lower Permian.

During the Lower Permian the Parana' Basin of southern Brazil was undergoing deglaciation. Although some topographic relief was present, the area was tectonically stable, and extensive glacigenic and cold climate deposits, including coals, were formed. In the geological literature of Brazil, a debate has been going on for several decades on the importance of such ancient glaciations in forming part of the Lower Permian sequence, and in particular on whether some of the coal-bearing stata are of interglacial origin, or if they were formed after the retreat of the glaciers.

Sedimentological and fossil (macroplants and palynology) analyses indicate that the coals of the southern states (Parana, S. Catarine and Rio Grande Do Sul) are all post-glacial in origin. Similarly to what happened in the Quaternary period in Canada, the climate warmed up very rapidly, geologically instantaneously, after the glaciers retreated, and vast peatlands developed in glacially re-molded valleys and in deltaic regions. However, coal-bearing strata of the Sao Paulo State at the northeastern margin of the Parana' Basin contain pre-Gangamopteris flora of possible late Carboniferous age, which changes in stratigraphically higher horizons into a Gangamopteris assemblage, all interbedded with diamicts, possibly of till origin. This implies a change from a colder older setting to a younger warmer one, and that the coals may be interglacial in origin. A similarity is found between the ancient Brazilian sequence and the much thinner interglacial (Sangamon) Quaternary sequence preserved in parts of the Hudson Bay Lowland (Bell Sea offlap sequence), buried under the latest Wisconsin glacial and Holocene post-glacial deposits (Tyrrell Sea offlap sequence).

DEVELOPMENT OF A RATING SYSTEM FOR SOIL COMPACTION SUSCEPTIBILITY

R.A. McBride

Introduction

Soil compaction research, originating largely in the U.S., has served to advance soil mechanical theory and has empirically examined the influence of traffic and tillage-induced compaction on crop growth and productivity under a limited range of soil conditions. It has made few inroads, however, into the estimation of soil structural or porosity change with variable wheel loadings or the ranking of a wide range of soil types by their inherent susceptibility to compression. The research project described here has these latter two aspects of soil compactibility as its objectives. This shortfall greatly limits our ability to rationally plan the use of our agricultural land resources or the sustainability of production and does little to advance the development of mitigative and corrective technologies or the application of preventive measures.

Soil consistency limits

Many important soil interpretations have been formulated from the measured mechanical behaviour of soils while in different states of consistency. Soil consistence is simply the physical manifestation of the forces of cohesion and adhesion in the soil and is, therefore, highly dependent on the Atterberg limits, whose determination has changed little since the inception of the standardized test procedures in 1932. The "upper plastic limit" (UPL), sometimes called "liquid limit", is the soil moisture content corresponding to a rather arbitrary division between the fluid and plastic states of soil consistency. Similarly, the "lower plastic limit" (LPL) is the soil moisture content delimiting the semi-solid (friable) from the plastic state. The numerical difference between these two measures is referred to as the "plasticity index" (PI) and denotes the range of moisture contents over which a soil exhibits plastic properties. Only "cohesive" soils (i.e. those with greater than about 5-10% clay content) have definable limits since neither very sandy nor silty soils possess elastic or plastic characteristics.

Soil consistency and compactibility

It is known that the soil consistency limits correlate very highly with many indices of soil compactibility (e.g. the Standard Proctor Maximum Dry Density and Optimum Moisture Content). Hence, it can be postulated that a compression-based test might well provide a more reproducible and meaningful measure of soil consistency. To test this hypothesis, a procedure is currently being refined involving the compression of soils under controlled loads while in a saturated and disrupted (remoulded) state.

Results of compression testing

Compression testing of 44 soil horizons sampled from the Regional Municipality of Niagara has shown that, in accordance with soil mechanics theory, a linear "virgin compression line"(VCL) can be plotted where $e = f(\log_{10}\sigma)$. Both the LPL and UPL of a soil can be plotted on its VCL but these indices have been shown not to occur at a unique or characteristic stress for all soils. The plastic soils used in this investigation equilibrated at their respective LPL's when subjected to stresses ranging as widely as 0.26 to 1.84 MPa. Similarly, the stress at the UPL ranged from 3.9 to 268 kPa, a barely mutually exclusive range relative to that of the LPL. These normal stresses, however, were found to be correlated with the clay and organic matter contents of the soil. The predictive capability of this compression-based test for the Atterberg limits was better for the LPL ($r^2 = 0.93$) than for the UPL ($r^2 = 0.79$).

Implications of the research

There are several areas for which these research findings have important implications. Firstly, the relationships revealed by this compression-based test procedure suggest that the LPL can be used as a reference point to help define the density-moisture-stress function in compaction modeling of Ontario soils. The "compression index" (Cc'), or the slope of the VCL, has been further shown through this research to be correlated to more readily accessible soil physical data (e.g. clay and organic matter contents, initial bulk density). Immediate use could thus be made of the existing and substantial soil consistency limit data in interpreting soil compactibility without the need for further soil mechanical testing. Much of this data is readily retrievable from computerized soil information systems in Canada and elsewhere.

Secondly, the possibility exists to unify what has for decades been a cumbersome, two-stage lab procedure for soil consistency limit determination. Any test procedure which directly yields comparable and more meaningful indices but which reduces or eliminates the inappropriately high level of subjectivity should be considered to supersede the current A.S.T.M. methods. At the very least, this new procedure defines the boundary between plastic and non-plastic soils more definitively than the current deunified tests.

Thirdly, it should be possible to better define the role of organic matter in the compaction process (e.g. content, type, degree of humification) with respect to its influence on the energy status of soil water and on soil strength parameters.

And finally, by linking soil compactibility and consistency, it may be possible to further refine the identification of optimum field conditions for tillage operations which will minimize subsoil compaction and maximize the efficiency of topsoil tillage.

The results and research implications described briefly above have been given more thorough treatment in the publications noted at the end of this report.

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THE EFFECT OF ROOT EXUDATES ON THE DISPERSIBILITY OF CLAY IN SOIL AGGREGATES

T. Pojasok and B.D.Kay

Degradation of structure preceded by a decrease in aggregate stability of agricultural soils has been found in Southern Ontario, Quebec and the Maritimes. The process has been related to reductions in yield of crops and thus, poses a serious threat to a sustained productivity of soils.

The hypothesis that corn root exudates increase the dispersibility of clay in soil aggregates by solubilizing polyvalent cations was tested. The importance of exudates as carbon substrates for microbial activity was investigated.

Corn and bromegrass were grown in sand culture for 30 days and 20 days, respectively. Sand was presterilized and then half of the pots were inoculated with soil microorganisms. Plants were pulse labelled with $^{14}CO_2$. Labelled root exudates were extracted by leaching sand with hot water (60°C) followed by 60% acetone. The following 8 exudate treatments were obtained:

BROME 1 - bromegrass exudate extracted by acetone from non-sterile sand
BROME 2 - bromegrass exudate extracted by water from non-sterile sand
BROME 3 - bromegrass exudate extracted by acetone from sterile sand,
BROME 4 - bromegrass exudate extracted by water from sterile sand

CORN 1 - corn exudate extracted by acetone from non-sterile sand
CORN 2 - corn exudate extracted by water from non- sterile sand
CORN 3 - corn exudate extracted by acetone from sterile sand
CORN 4 - corn exudate extracted by water from sterile sand

Samples of the exudates were incubated for 5, 24, and 96 hours with 1-2 mm sized soil aggregates. The amounts of dispersed clay sized particles (%DC) were measured after each incubation period and are shown in Figure 1. The amounts of Ca, Mg and Fe released into solution were measured after the incubation periods and are shown in Figure 2. The amounts of $^{14}CO_2$ and total CO_2 evolved after each incubation period were measured and data are shown in Figures 3 and 4.

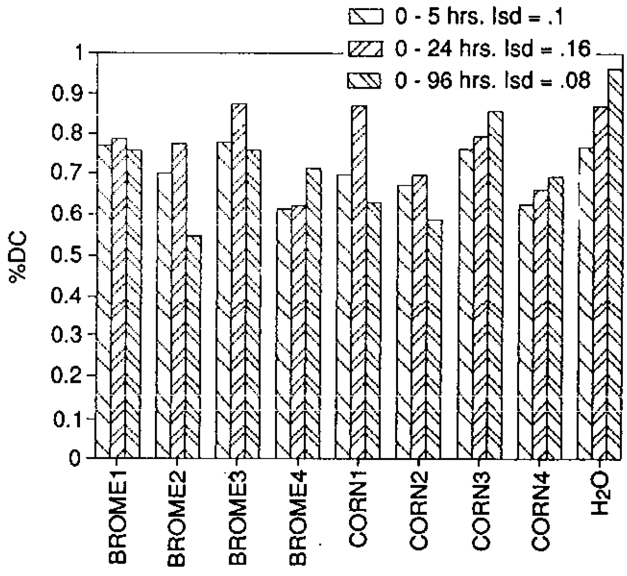

Figure 1. %DC after the incubation of soil aggregates with exudates.

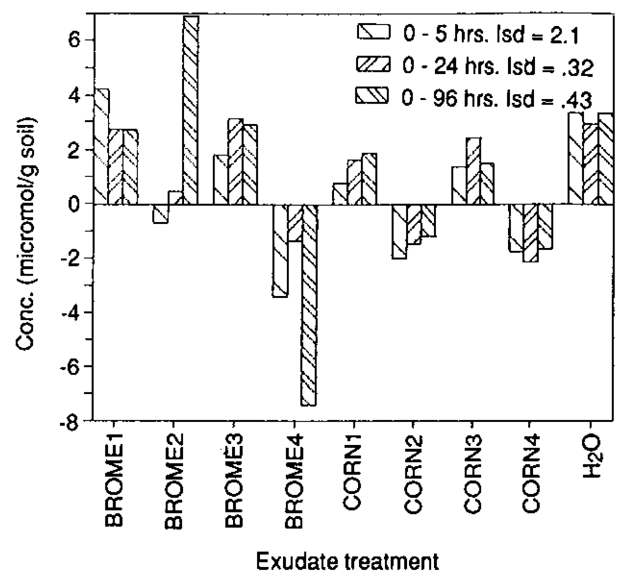

Figure 2. Concentrations of the total of Ca, Mg, and Fe released into solution after the incubation of soil aggregates with exudates.

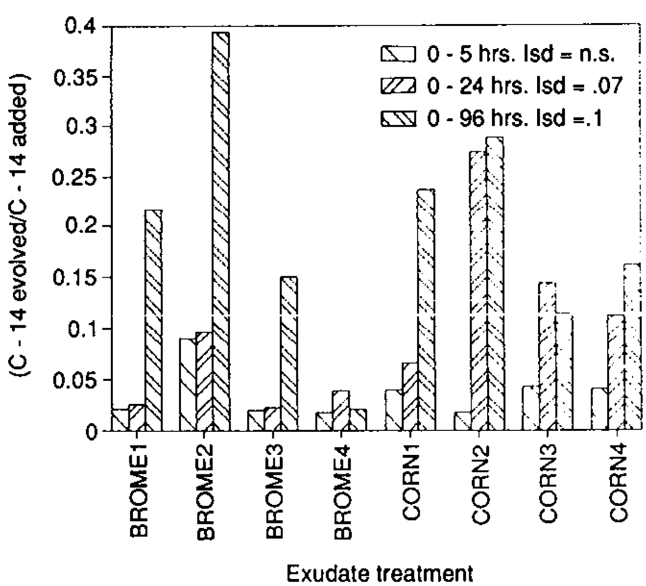

Figure 3. The proportion of ^{14}C added that evolved as $^{14}CO_2$ after the incubation of exudates with soil aggregates.

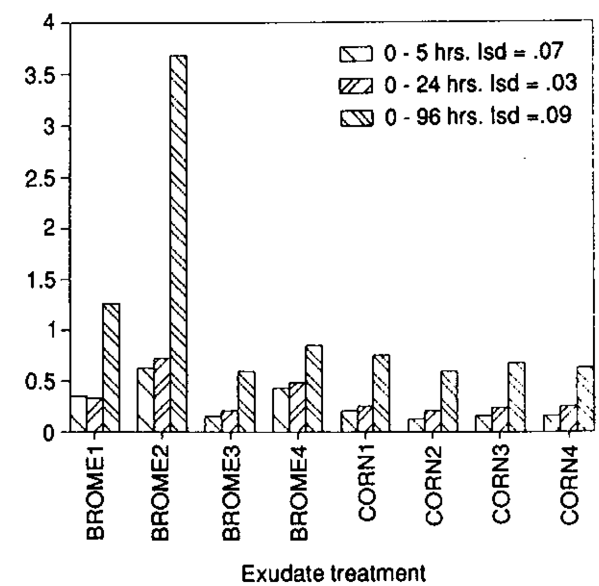

Figure 4. The proportion of C added that evolved as CO_2 after the incubation of exudates with soil aggregates.

Contrary to the hypothesis, the %DC decreased after exudates were incubated with soil aggregates relative to the water control. No differences appeared between the %DC of corn and bromegrass exudates.

Data in Figure 2 indicated that some exudate material had solubilized cations, however, the adsorption of cations from other exudate solutions occurred. On average, more cations were released when corn exudates were incubated than when bromegrass exudates were used.

Exudates, by decomposing and evolving as labelled CO_2 (Figure 3), appeared to act as carbon substrates for microbial activity which increased upon the addition of exudates as shown by the total CO_2 evolved (Figure 4).

Stepwise regression analyses of the data showed that the variation in %DC was explained by the amount of cations released into solution, the $^{14}CO_2$ and total CO_2 evolved. An increase in the release of cations into the solution resulted in the flocculation of clay particles. Also, increased decomposition of exudate material and increases in microbial activity were related to a decrease in %DC probably due to the production of microbially derived organic binding agents such as polysaccharides.

It was concluded that exudates, incubated with soil, stabilized aggregates by influencing microbial activity and the amount of cations released into solution.

INITIAL MEASUREMENTS ON THE INDEX OF SOIL QUALITY

R. Protz, D. McCabe and E. Dickson

This project was initiated in 1987 to develop an index of soil quality based on differences between never cultivated and cultivated soils. We first measured labile carbon, faunal mobility and soil compressibility, on four never cultivated soils, from the Lake Erie Drainage Basin. As there can be a wide range of variation in microniche distribution and because the greatest variations in diurnal temperature occur within the top 5 cm, we decided to sample one cm thick layers over an area of 50 x 50 cm. This volume represents the equivalent of 1/4 of a pedon, thus is assumed to be a representative sample. As most biological activity occurs in the Ah horizon we sampled only to the 16 cm depth. The LF horizon and the 1987 leaf fall were collected from a 1 m^2 area.

To estimate the bulk density in each 1 cm layer triplicate cores were collected from the 0-5, 5-10, and 10-15 cm layers. The variation in bulk density was greatest (0.8 to 1.4 gm cm^{-3}) within the Fox loamy sand, Smithville silty clay and Smithville Silty Clay Loam (Fig. 1). Bulk density only varied from 1.0 to 1.3 gm cm^{-3} in the Donnybrook sandy loam. This variation in bulk density correlates closely to variations in daily temperature changes with depth.

Soil strength or compressibility measurements have been made on 0-1 cm and 12-13 cm layers from each of the four profiles. The greatest differences in consolidation occur between the Smithville silty clay (Fig. 2) and the Fox loam sand (Fig. 3). The least variation within the Donnybrook loamy sand (Fig. 4) and an intermediate amount for the Smithville silty clay loam (Fig. 5). Even though these measurements were made on soil material that was air dried and then passed through a 2 mm sieve the differences are significant and probably reflect the influence of diurnal temperature changes causing more complete mixing of the organic matter and mineral particles and the larger amount of organic matter in the 0-1 cm layer. Measurements on intervening layers fall between two lines for each profile. To estimate faunal activity ^{137}Cs measurements were made on each sample for the four profiles (Fig. 6). The presence of LF horizons indicates that the yearly leaf fall is not incorporated into the soil (Table 1). The Fox sandy loam has a 2-3 cm thick LF horizon. The presence of an LF horizon was also noted in the Donnybrook and Smithville silty clay loam. The distribution of ^{137}Cs with depth (Fig. 6) indicates that earthworms and other burrowing fauna incorporate all the yearly leaf fall, whereas the absence of earthworms in the Fox loamy sand causes the accumulation of an LF horizon and the continual recycling of the ^{137}Cs in organic and possibly mineral form. The content of labile carbon[1] in each of four profiles is shown in Fig. 7. The largest amount of labile carbon occurred in the Smithville silty clay loam which probably has the highest available moisture and faunal activity as indicated by the nature of void space in Fig. 8. Research on the development of the index is continuing.

Table 1. Weight 1987 leaf and LF horizons in gm m^{-2}

	Fox LS	Donnybrook SL	Smithville SiL	Smithville SiC
	(16)	(46)	(36)	(56)
1987 Leaf	496	436	370	306
LF	2425	1715	509	867

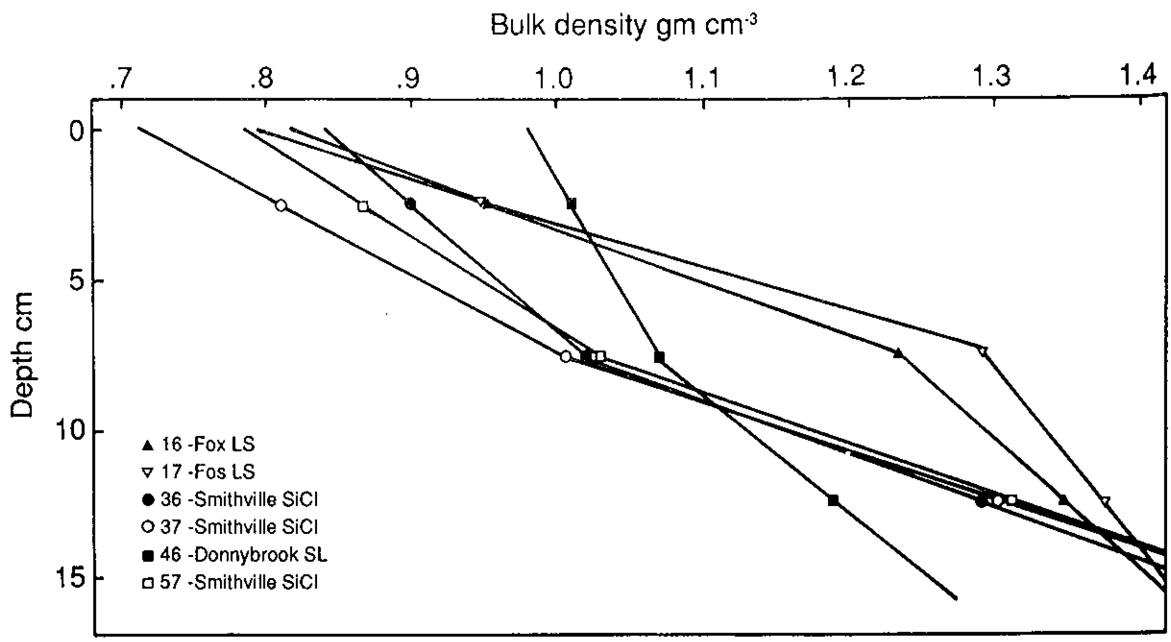

Figure 1. Bulk density (g/cm3) variations for the Fox loamy sand, Smithville silty clay, and Donnybrook sandy loam.

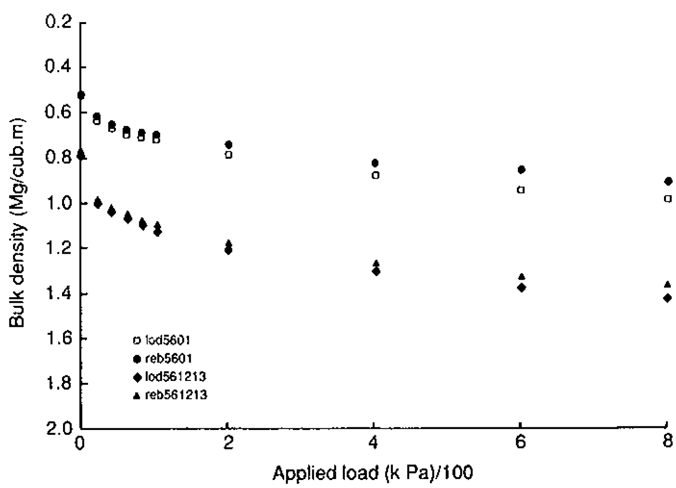

Figure 2. Compressibility Smithville silty clay for the 0-1 cm and 12-13 cm depth.

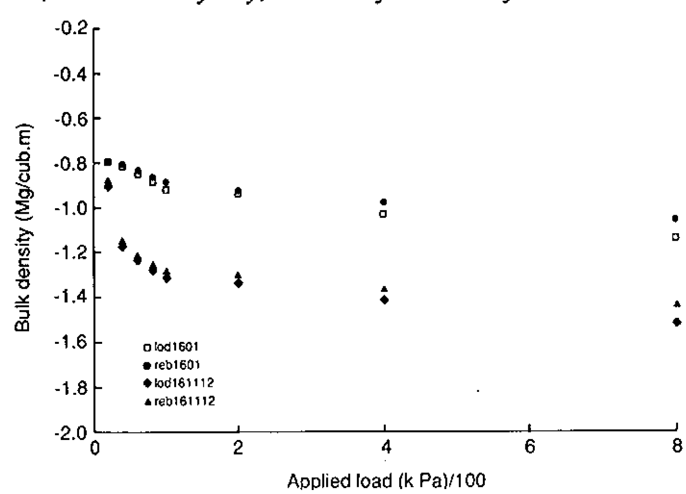

Figure 3. Compressibility of the Fox loam sand for the 0-1 cm and11-12 cm depth.

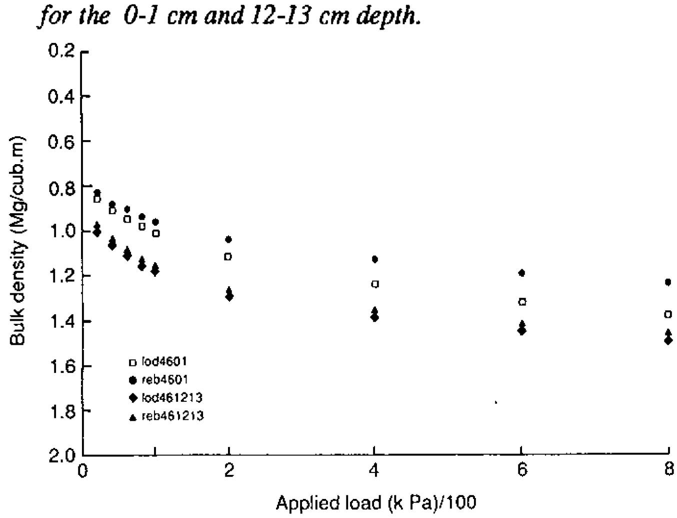

Figure 4. Compressibility of the Donnybrook loamy sand for the 0-1 cm and 12-13 cm depth.

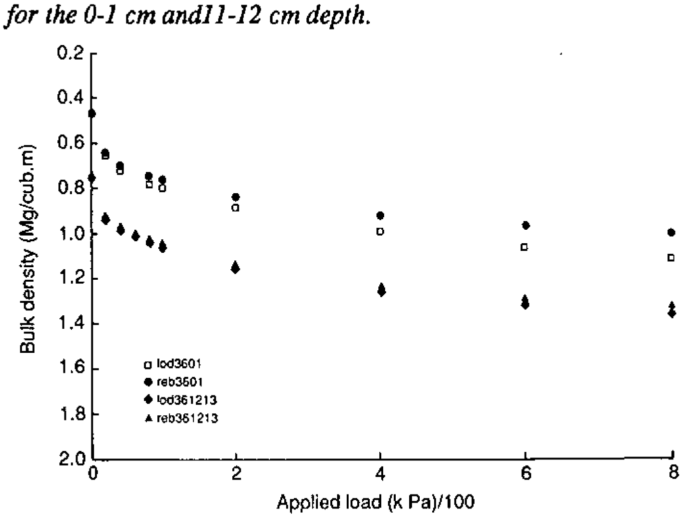

Figure 5. Compressibility of the Smithville silty clay loam for the 0-1cm and 12-13 cm depth.

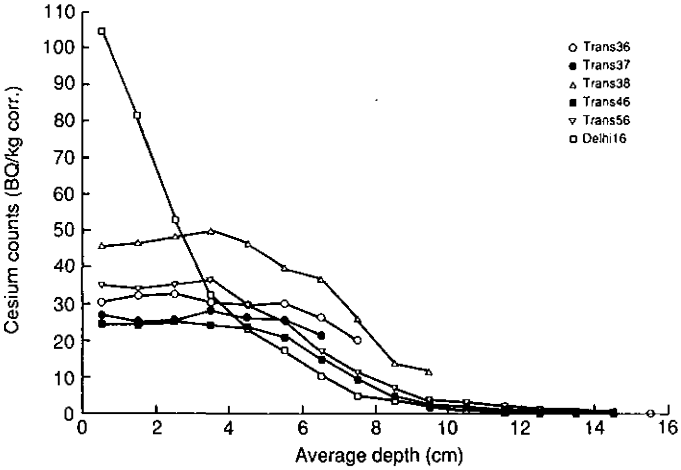

Figure 6. Cesium measurements for each profile.

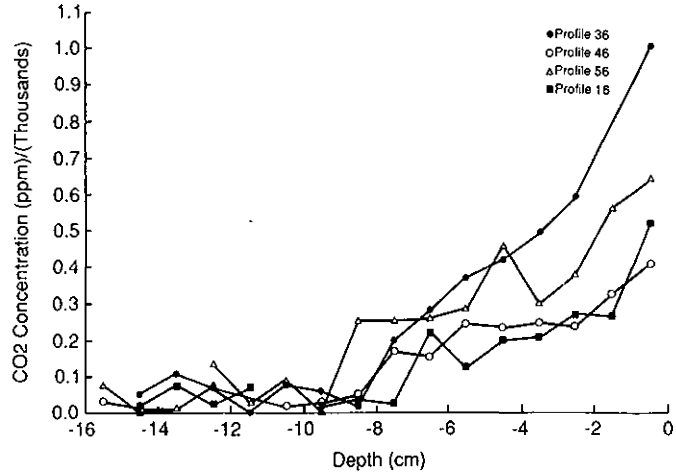

Figure 7. Labile carbon concentration for each profile.

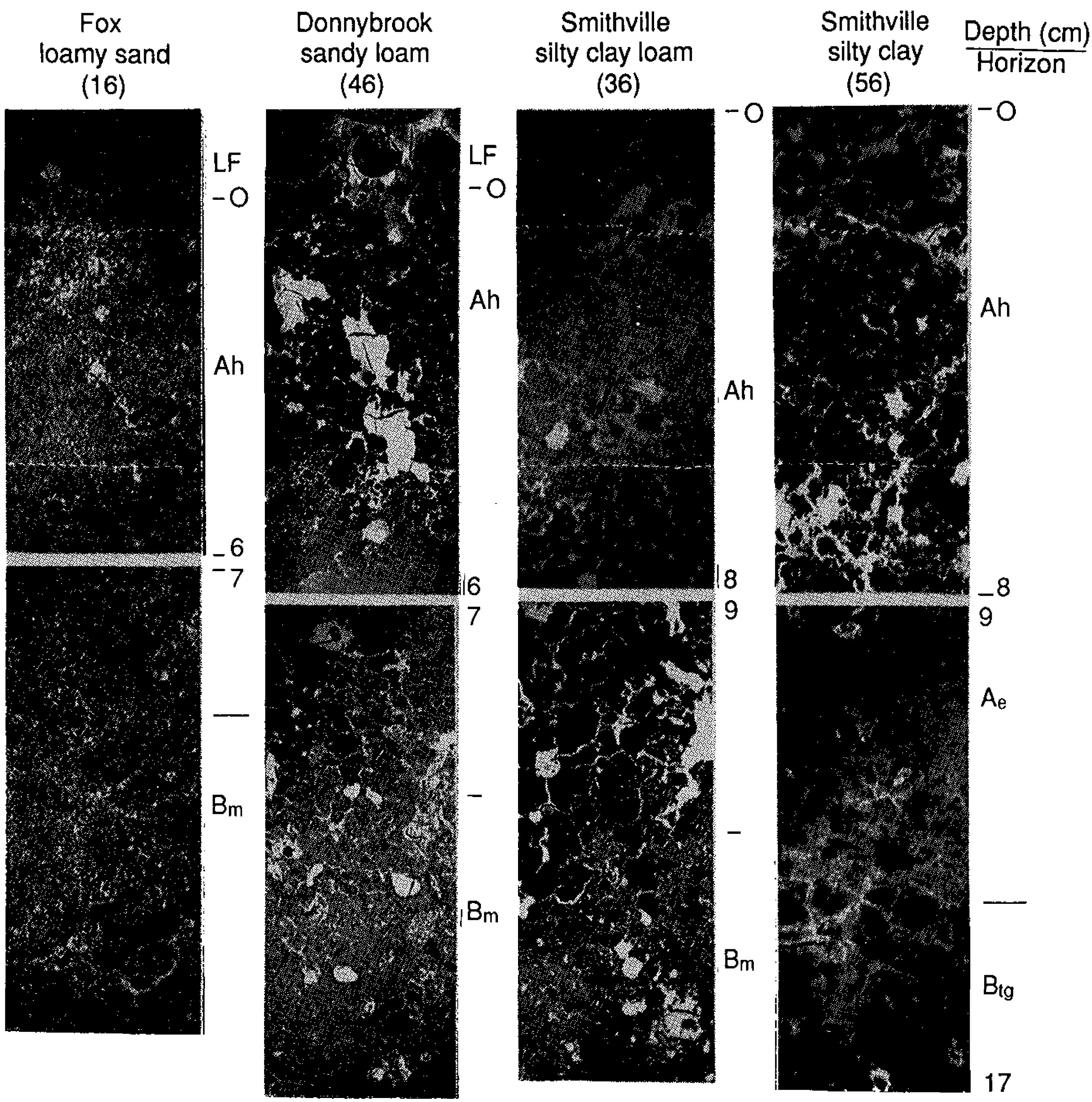

Figure 8. Thin sections of the Fox loamy sand, Donnybrook sandy loam, and the Smithville silty clay and silty clay loam.

EFFECTS OF PH ON BORON RETENTION

C. Su and L.J.Evans

The Ap horizon of an acid soil (pH 4.8) (Welland Series- Orthic Humic Gleysol) was used to investigate the influence of pH on boron retention. The pH of the soil was increased by the addition of $CaCO_3$ or $MgCO_3$ and the amount of $CaCO_3$ or $MgCO_3$ required for the desired pH's were determined using the SMP buffer method. The soil was passed through a 1 mm sieve, added $CaCO_3$ or $MgCO_3$ mixed thoroughly and the soil incubated for one month under at field capacity (32% w/w, bulk density 1.2 g cm^{-3}). After incubation, the soils were air dried, ground and again passed through a 1 mm sieve.

Boron retention by $CaCO_3$- or $MgCO_3$-amended soils was studied by shaking 5 g of soil in 50-ml polypropylene centrifuge tubes containing 15 ml of solution with boric acid in 0.01N $LiNO_3$ solution at room temperature (25± 2°C) for 24 hours. The initial boron concentrations were 1, 2, 4, 6, 8, and 10 g ml^{-1}. After equilibrium, the suspensions were centrifuged and aliquots of supernatant were analysed for pH and for boron. B was determined using the Azomethine-H method. The amount of retained boron was calculated by determining the difference between the amount of B added and that found in solution, and correcting for the negative retention of boron.

Boron retention isotherms at different pH's for the two amended soils are shown in Figs. 1 and 2. It was found that B retention increased as the pH increased and that at equivalent pH's there was more retention by $CaCO_3$-amended soils than by the $MgCO_3$-amended soils. The effect of pH on boron retention can be explained by the nature of ionization of boric acid.

$$B(OH)_3 + H_2O = B(OH)_4^- + H^+ \qquad pK_a = 9.24$$

The increase in pH causes an increase in $B(OH)_4^-$ and this results in an increase in retained boron, the maximum amount of retention of anions occurring at a pH just below the pK_a of the conjugate acid.

The reactions between boric acid and soils may involve the formation of complexes of borate with clay surfaces. Two kinds of complexes have been suggested: outer-sphere complexes in which electrostatic forces of attraction play an important role, and inner-sphere complexes in which specific chemical bonds are formed. The latter complexes may include both mono-dentate and bi-dentate complexes, Table 1.

The possibility of the formation of insoluble Ca/Mg-borate minerals during the incubation experiments was investigated by constructing phase diagrams using the reactions shown in Table 2. Results indicated that the experimental soil solution were all undersaturated with respect to all the Ca/Mg-borates considered, except for the mineral nobleite. Precipitation of nobleite may be another mechanism of boron retention in $CaCO_3$ amended soils.

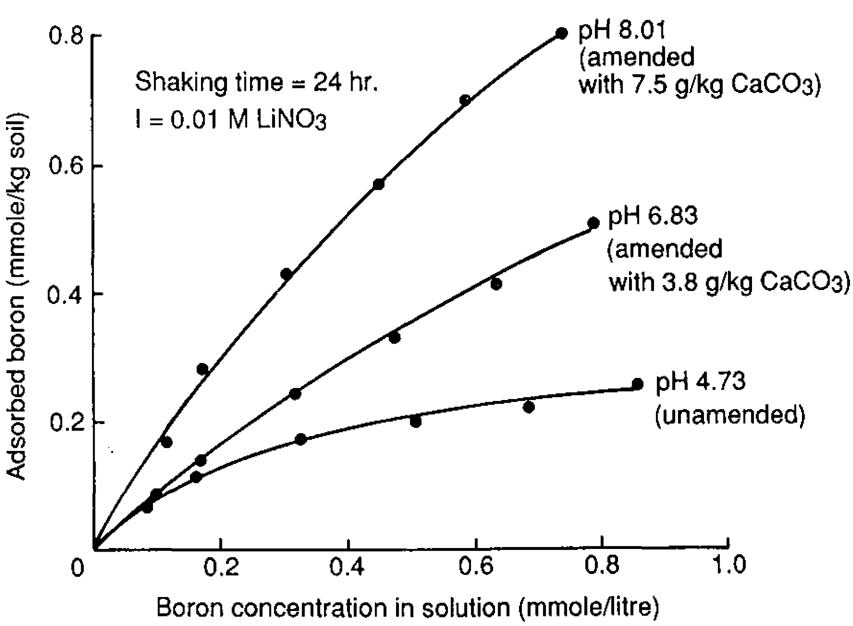

Figure 1. Boron retention isotherm for CaCO3 amended soil.

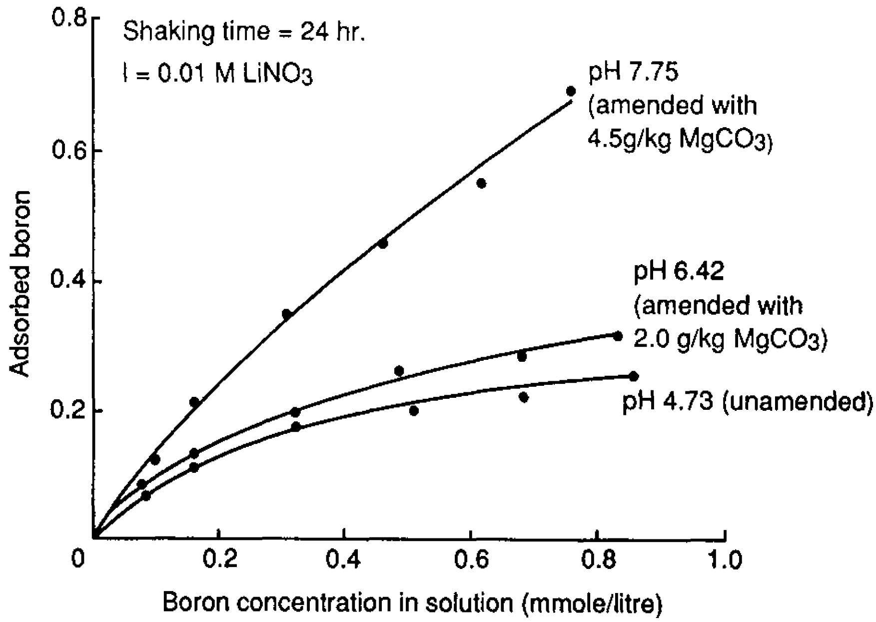

Figure 2. Boron retention isotherm for $MgCO_3$ amended soil.

Table 1.

Outer sphere complexes

$$\equiv Al\text{-}OH_2^+ + B(OH)_4^- = \equiv Al\text{-}OH_2^+.B(OH)_4^-$$

Inner sphere complexes

a) Mono-dentate

$$\equiv Al\text{-}OH^+ + B(OH)_4^- = \equiv Al\text{-}O\text{-}B\begin{array}{l} / \ OH \\ \\ \backslash \ OH \end{array} + H_2O + OH^-$$

b) Bi-dentate

$$\begin{array}{l} \equiv Al\text{-}OH \\ \\ \equiv Al\text{-}OH \end{array} + B(OH)_4^- = \begin{array}{l} \equiv Al\text{-}O \ \backslash \\ \qquad\quad B\text{-}OH \\ \equiv Al\text{-}O \ / \end{array} + 2H_2O + OH\text{-}$$

Table 2. Congruent dissolution for some Ca/Mg-borate Minerals

Reaction	ΔG_r^o (kJ/mol)
$Ca^{2+} + 3B(OH)_4^- + H^+ === Ca[B_3O_3(OH)_5].4H_2O$ Inyoite	-100.08
$Ca^{2+} + 3B(OH)_4^- + H^+ === Ca[B_3O_4(OH)_3].H_2O + 4H_2O$ Colemanite	-100.04
$Ca^{2+} + 6B(OH)_4^- + 4H^+ === Ca[B_6O_9(OH)_2].3H_2O + 10H_2O$ Nobleite	-272.50
$Mg^{2+} + 2B(OH)_4^- === Mg[B_2O(OH)_6] + H_2O$ Pinnoite	-26.23
$Mg^{2+} + 3B(OH)_4^- + H^+ + H_2O === Mg[B_3O_3(OH)_5].5H_2O$ Inderite	-96.15
$Mg^{2+} + 4B(OH)_4^+ + 2H^+ === Mg[B_4O_4(OH)_6].6H_2O$ Hungchoite	-152.05
$2Mg^{2+} + 12B(OH)_4^- + 8H^+ === 2Mg[B_6O_7(OH)_6].4.5H_2O + 13H_2O$ McAllisterite	-261.79

THE KINETICS AND MECHANISM OF BORON RETENTION

C. SU and L. J. EVANS

A purified Na-clay mica (Fithian illite) and the Ap horizon from a Humic Gleysolic soil (Welland Series) adjusted to pH 7.8 by the addition of $CaCO_3$ were used to investigate the kinetics of boron retention. The clay fraction of the Fithian illite was found to contain small amounts of kaolinite and vermiculite in addition to clay mica. A further purification of the illite sample involved heating the sample at 450°C for 20 hours to destroy kaolinite and extracting the sample with acid potassium oxalate to remove amorphous aluminosilicates and to convert vermiculite to clay mica. The clay was Na-saturated with NaCl and the excess Cl^- was removed by dialyses. A re-examination of the X-ray diffraction pattern now showed the absence of kaolinite and vermiculite. The final clay sample was dominated by clay mica, with only a small amount of quartz.

The kinetics of B adsorption by the Na-clay mica and the $CaCO_3$-amended soil were investigated by determining the amount of B (as H_3BO_3) adsorbed by the samples at time intervals of 0.5, 1, 4, 24, 48, 96, 144 and 336 hours. In these experiments, the initial B concentration was 6 g/L, and the ionic strength 0.01 M using $LiNO_3$ as the indifferent electrolyte. It was found that B adsorption by both the Na-clay mica and the $CaCO_3$-amended soil agreed with pseudo-first order reactions, i.e. there was an initial fast reaction between B and adsorbents followed by a slower reaction.

The following equation was used to describe the first-order reaction.

$$C = C_0 e^{-kt}$$

where C = concentration of B(mmole/L) at time t(hr.);
C_0 = initial concentration of B (mmole/L) at time 0;
k = adsorption reaction constant ($hr.^{-1}$).

The half-time of the reaction is the time needed to reduce the initial concentration of the reactant(B) to half.

$$t_{1/2} = Ln2/k$$

The half-time of the two pseudo-first order reactions were calculated as 250 and 2708 hours (10 and 113 days) for the Na-clay mica, and 1159 and 3474 hours (48 and 145 days) for the $CaCO_3$-amended soil respectively. For the Na-clay mica, the faster reaction ended after 48 hours, while for the $CaCO_3$-amended soil it ended after 144 hours, before commencement of the slower reactions. It was observed that the pH values of the supernatant solution increased with reaction time in both cases. This suggested a possible mechanism of B adsorption with the clay mica and with the soil that involved ligand exchange between borate $B(OH)_4^-$ and the surface OH^-'s of clay minerals. However the increase in pH's alone could not account for the total amount of B adsorbed through ligand exchange reactions. The presence of two different reactions with different kinetics suggested that after the first faster reaction a second mechanism may be that B is adsorbed by diffusion into the tetrahedral sheet of the clay mica. Direct evidence of this migration will be investigated in another experiment using NMR and IR spectroscopy.

A MICROMORPHOLOGIC EXAMINATION OF FRACTURES IN GLACIAL TILL FROM ALBERTA, CANADA*

S.J. Sweeney, R. Protz and M.J. Hendry

Many glacial tills in the Interior Plains Region of North America are fractured. A 5 metre-deep study pit was excavated in till at a site in the Milk River Watershed of southern Alberta. A chernozemic soil has developed from the glacial till parent material at this site. The clay-textured, Bt horizon exhibits strong columnar pedality and hence the continuous macropores in this soil horizon have strong vertical orientation. The underlying, ligniferous glacial till ranges in texture from loam to clay. The till is brownish yellow in the upper C horizon and becomes darker brown and more gray in colour with depth. This change in colour with depth corresponds to the presence of three zones within the till in the study profile: a) an upper zone in which oxidized iron outlines the fractures, b) a middle, jointed-till, transition-zone with both iron oxides and manganese on ped surfaces and c) a lower zone dominated by manganese-coated planar fractures.

Oriented, undisturbed samples of the till were collected from each zone in the study pit. These samples were maintained at their natural field water contents until the soil water was displaced with acetone in the laboratory. The till samples were then impregnated with 3-Hydroxy-butyl methylmethacrylate (3HBMA) resin containing Uvitex-OB (Ciba-Geigy) UV fluorescent dye. The fractures (void space) were examined using high-contrast black and white photographs of polished faces of the serially-sectioned samples taken under UV illumination. Imaging of these photographs was performed on a Kontron Image Analyser. The fracture (void) network within the glacial till was quantified for size, shape, orientation and interconnectivity.

* Paper forms part of the Ph.D. thesis work of the senior author and will be presented at the International Working Meeting on Soil Micromorphology, Meeting of Sub-Commission B of the International Society of Soil Science, San Antonio, Texas, U.S.A., July 10-15, 1988

TURBULENT DIFFUSION PROCESSES AND TRACE GAS DETECTION

G.W. Thurtell

Turbulent diffusion processes:

We have made major contributions to both the experimental and theoretical research developments that are rapidly improving our understanding of turbulent diffusion within and above plant canopies. This is of major importance to all agricultural and environmental problems which relate to the transport of gaseous or particulate material in the natural environment. We also believe that these theoretical developments are generally applicable to all turbulent transport processes including both industrial and "Hi-tech" areas, (Thurtell and Thurtell, 1988). In 1981 we showed (Wilson et al I, II, III) that these diffusion processes cannot be described by the familiar linear equation

$$F = -K\, dc/dx \qquad (1)$$

and, in the same series of papers, we presented a "Trajectory simulation model" we had developed for canopy diffusion.

There are several reasons why eqn. (1) can never describe crop canopy transport processes and why canopy transport will, in general, be different for each diffusing property. At any point x the diffusion process is not only a function of the characteristics of the turbulent flow field but also of the distance between the source of the diffusing material and the point x (Taylor 1921). When this distance becomes very large when compared to the diffusion length scale the solution may approach eqn. (1), but under extreme conditions, e.g. a plant canopy, the diffusion process can even reverse direction, resulting in an apparently negative value for K in eqn. (1). The main feature of our Trajectory Model was its ability to correctly account for the positions of the sources of the diffusing materials. More recently the turbulent diffusion of gases and particulates within and above vegetation canopies has been receiving increasing attention by researchers around the world.

During the summers of 1984 and 85 we conducted line source gaseous release experiments at the Elora Research Station, Elora Ontario, (Leclerc and Thurtell 1986, a, b, Leclerc 1987, Leclerc and Thurtell 1987, b, Leclerc and Thurtell 1988). This experiment provided plume spread concentration data at two distances downwind from the source. The data were compared with Trajectory Model predictions and while the model did account for the distance from the source it did not handle well the influence of the strong curvature in the vertical profile of the level of turbulence that typically occurs within plant canopies. As a result the Trajectory Model was modified to improve this feature (Leclerc 1987). The need for much more detailed data sets was also clearly indicated.

In 1986-87 we participated in a cooperative field experiment at Borden, Ontario (Leclerc 1987, Leclerc and Thurtell 1987a, Shi 1987). The latter was funded by Environment Canada. The participants at Borden included R. H. Shaw, Univ. of Cal., Davis, G. den Hartog and H. H. Neumann, Atmospheric Environment Service, and G. Kidd, M. Y. Leclerc, G. Shi, and G. W. Thurtell, U. of Guelph. A total of ten three-dimensional sonic anemometers were mounted within and above the approximately twenty meter high forest on two towers, he tallest of which was 43 meters. Standard supporting micrometeorological data were also collected. We originally hoped to repeat the Elora line source release experiment in the much more complete Borden experiment but this proved impossible due to lack of funds. It is expected, however, that the high quality data collected will result in significant progress in the development of canopy models over the next several years (Thurtell, 1988, a, b).

Diode lasers for high speed trace gas detection:

The importance of monitoring the concentrations of trace gases, (nitrogen oxides, NH3, CH4, O3, SO2 etc.) in the atmosphere has been recognized for several years. Since the number of gases involved is large and their concentrations are typically very small, progress in this area has been slow. In many cases it is not only the concentrations, but also the flux densities that are required and until recently these measurements have been impossible for many of these gases. The use of diode lasers as tunable infrared sources offers an attractive solution to this problem. They have been used in gas monitoring systems for several years and high sensitivities have been achieved. Ontario Hydro has one of these systems that was designed for eddy-correlation measurements and we are fortunate to have been associated with that program, (Edwards et al 1987). We have received a contract from Environment Canada to design a new prototype laser-based system using newly developed lasers and, most importantly, built in microprocessor based digital data handling and signal analysis technology. We are proposing to design and build a field instrument modeled after the prototype, and to field test it for trace gas measurements. It is expected that concentrations and fluxes of the nitrogen oxides will be measured first.

We believe the capability to accurately measure, for the first time, both the atmospheric concentrations and fluxes of the nitrogen compounds, N_2O, NO, NO_2, NH_3, etc. will make a significant contribution to Ontario agriculture.

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PLANT WATER RELATIONSHIPS

G.W. Thurtell

A whole-plant controlled-environment chamber was designed and tested (Graham and Thurtell 1987 a,b,c). The CO_2 and H_2O vapour concentrations were computer controlled and the temperature was continuously maintained near ambient values. The humidity control was achieved with the use of the desiccant, "Dririte", which is suitable for this purpose because it neither adsorbs nor releases significant quantities of CO_2 after being properly preconditioned. By monitoring the increasing weight of the desiccant with a "Sartorius" electronic balance a continuous record of the transpiration rate was obtained. The CO_2 concentration was controlled by adding either pure CO_2 to replenish that used by the plant or CO_2 free air to compensate for plant respiration. The rate of gas addition was quantitatively controlled by "Tylan" gas flow controllers allowing the rate of either net photosynthesis or respiration to be measured. Leaf temperatures were monitored under field conditions for three growing seasons by simple infrarethese chambers, each large enough to enclose a mature corn plant. The experiment was designed to determine the extent to which photosynthesis would be affected by increases or decreases in the rate of transpiration under a range of soil water conditions. The effects of natural environmental variability, e.g. cloudiness, which reduces the efficiency of field experiments of this type, were largely removed by the use of two chambers simultaneously exposing similar plants to different environments.

The results of the chamber evaluation tests showed that the control and measurement systems functioned as predicted and that all features of the design were well suited for this research. With continued use under field conditions these chambers have proven to be very reliable and we remain confident in the accuracy of the results.

The photosynthesis and transpiration data indicate that increasing transpiration rates, (greater vapor pressure deficits), do result in reduced rates of photosynthesis even when the soil is close to field capacity. How rapidly this effect will increase as the soil conditions become drier was measured in 1987, (Berard, R.G. and G.W. Thurtell, 1987), but the data analysis has not yet been completed. We believe this data will be valuable for determining the factors limiting economic corn yield and that more data of this type should be obtained, not only for corn, but also for other field crops. In addition, plant chambers similar to these are probably the only currently available technique for studying the efficiency of undisturbed root systems in the natural environment.

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CHARACTERIZING PHYSICAL PROPERTIES OF POTATO PRODUCING SOILS

R. van den Broek, W. Stevens and D.M. Brown

A detailed survey at specific sites on three farms in the Alliston area was conducted to determine the variability and characterize these soils for certain physical features and horizon depths. A total of 40 profiles were sampled on the three farms. Statistical tables comparing the physical features for each horizon at each site were prepared for the following features:

Ap
- a) Depth
- b) Organic Matter
- c) pH
- d) Texture

Bt
- a) Depth to Bt
- b) Thickness
- c) Texture range
- d) Clay content
- e) Increase in clay content

a) Depth to soil discontinuity
b) Sand content in soil discontinuity
c) Silt content in soil discontinuity
d) Increase in silt content in soil discontinuity
e) Clay content in soil discontinuity

Ck a) Depth to parent material
b) Texture range
c) Sand content
d) Silt content
e) Clay content
f) $CaCO_3$ content
g) pH of parent material

An example of the variability in these Alliston fine sandy loam soils of the Tioga series is illustrated by the silt content in the parent material (Fig. 1). The mean value is for five profiles in a 100 m^2 sampling area, along with the high and low of the five samples for each of the eight sites (1A to 6).

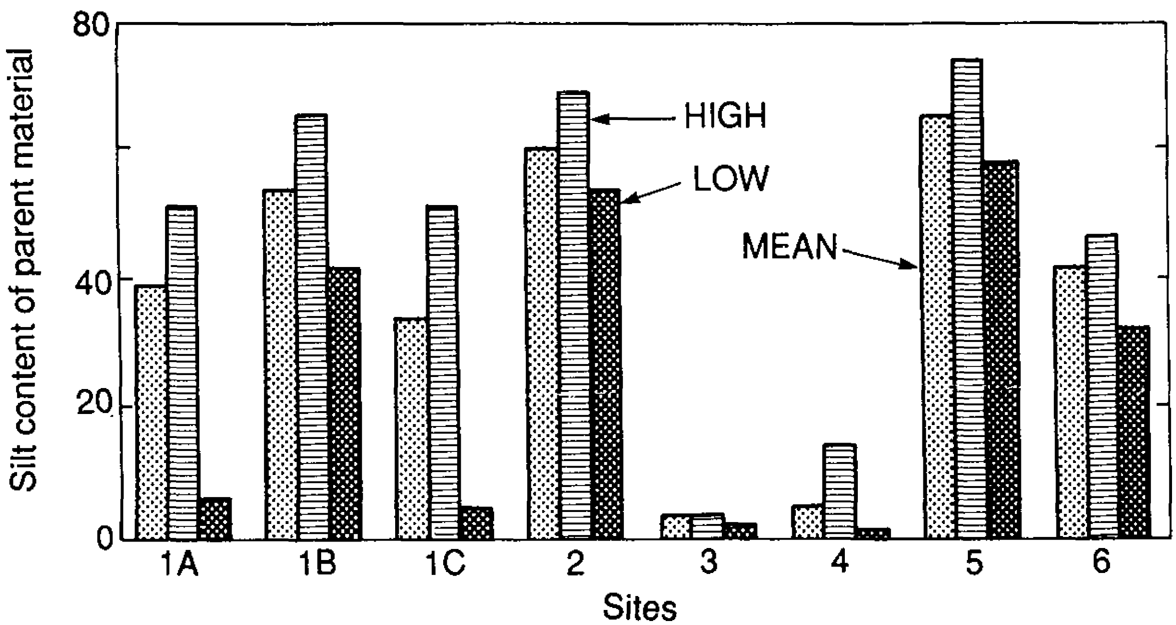

Figure 1. Silt content (%) of parent material in Alliston fine sandy loam from detailed soil survey at eight sites on three farms near the Nottawasaga river south of Alliston, showing mean , low and high percentage for five samples at each site.

CARBONATITES OF SOUTHWEST AND WEST TANZANIA: CHEMICAL AND REGIONAL ASPECTS

P. van Straaten

Three major periods of carbonatite/alkaline intrusions are recognized in Tanzania: late Proterozoic (750-680 Ma), Cretaceous (120-100 Ma) and Cenozoic (40-0 Ma). Virtually all carbonatites were emplaced outside the Archean Tanzania craton and their emplacement is spatially associated with deep structural anisotropies, with repeatedly rejuvenated fault and shear zones. The Cenozoic carbonatites occur at the eastern margin of the craton and the ten Mesozoic and Proterozoic carbonatite/alkaline complexes described in this paper occur West and Southwest of the craton.

With the exception of the 1040 Ma Ngualla carbonatite, all Proterozoic complexes were intruded during or shortly before the initial phase of the Pan-African thermotectonic rejuvenation. The Cretaceous carbonatites intruded into normal fault zones in a tensional stress field well after the main post-Karroo/pre-Cretaceous rifting phases and the breakup of Gondwanaland. The latest carbonatite event is clearly associated, at least spatially, with Tertiary-Recent rifting.

The sequence of emplacement from sovite through magnesio-carbonatite to ferro-carbonatite is illustrated at the well differentiated Ngualla and Panda carbonatites. Economically important Nb and P mineralizations are associated with early phases of the Panda carbonatite intrusion, concentrations of REE with late stage carbonatite phases of the Ngualla and the Songwe Scarp carbonatites.

SPATIAL AND TEMPORAL DISTRIBUTION OF SOIL WATER CONTENT IN THE TILLED LAYER UNDER A CORN CROP

I. van Wesenbeeck and G. Kachanoski

Limited information is available regarding the spatial distribution of surface layer(0-0.2m) soil water content under row crops. Surface soil water content affects many soil processes including microbial biomass activity,nutrient uptake, and N-cycling. During the 1986 growing season, measurements of the spatial distribution of the surface layer soil water content under a corn crop (Zea Mays L.) were obtained. The objectives of the study were i) to obtain data on the spatial distribution of plough layer soil water content below a row crop throughout the entire growing season, and ii) to use the temporal dynamics of soil water content to examine the spatial patterns of soil drying and recharge below the crop.

The study area was located at the Elora Research Station in a field consisting predominantly of a London silty clay loam soil. The study site was fall ploughed and seeded to corn on May 12, 1986, in 0.8 m rows. The area had been in corn for at least three years. Soil water content was measured using the Time Domain Reflectometry (TDR) method. The TDR method provides a low-cost, quick, accurate, and non-destructive method of measuring volumetric soil water content. At the time of emergence, the TDR probes were installed in a single transect, perpendicular to the corn rows, at 0.2 m intervals. Thus, between every two rows of corn in the transect a TDR probe was situated in each row, directly between the rows (interrow), and halfway between each row and interrow position (quarter row). This gave 25 row, 25 interrow, and 50 quarter row positions for soil water measurements. Each TDR probe was pushed easily into place by hand to a depth of 0.2 m. The four access boxes, each with 25 probes attached were situated 5-6 m away from the transect. Once the entire system was in place it was not necessary to approach within 5m of the transect. Figure 1 shows a schematic diagram of the TDR soil-water monitoring system.

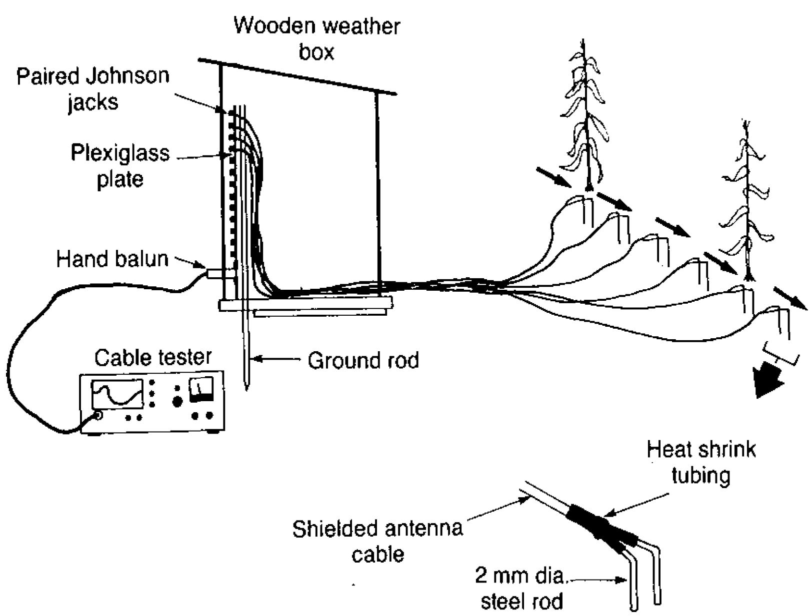

Figure 1. Diagram of the TDR soil water monitoring system.

Soil-water measurements were taken every 1-2 days at approximately 11:00 A.M. throughout the 1986 growing season. Measurements from all 100 locations could be accomplished in thirty minutes by one person.

A drying coefficient, K_i (m3/m3/d) was obtained for every major drying period, and sampling location i, from a least squares fit of

$$\theta_{i,t} = \theta_{i,o} e^{-(K_i t)} \tag{1}$$

where $\theta_{i,t}$ = soil water content (0-0.2m, m3/m3) at relative time t(day) and location i, $\theta_{i,o}$ = soil-water content(m3/m3) at the start of the drying period (t=o), after recharge event), and K_i=drying rate constant(m3/m3/d).

Coefficients of variation and skewness were calculated for the temporal probability distribution function at each spatial location, and also for the spatial probability distribution function at each measurement date. Soil water measurements were taken on 69 dates giving a total of 6900 individual measurements.

RESULTS AND DISCUSSION

Mean surface soil-water contents(0-0.2m,m^3/m3) at the row($\bar{\theta}_r$), interrow ($\bar{\theta}_i$) and quarter row ($\bar{\theta}_q$) sampling locations for several crop growth stages are given in Table 1. The $\bar{\theta}_i$ values were significantly (0.05 probability level) larger than the $\bar{\theta}_r$ values at all growth stages except the five-leaf stage. The $\bar{\theta}_q$ values were lower than the $\bar{\theta}_i$ values but greater than the$\bar{\theta}r$ values. Similar trends in values were observed for almost all of the 69 measurement dates indicating a systematic spatial distribution of soil water content in the plough layer throughout the growing season.

The mean drying coefficients estimated from equation (1) for the row ($\bar{K}_r$), interrow($\bar{K}_i$), and quarter row ($\bar{K}_q$) locations for three drying periods during the growing season are given in Table 2. The drying coefficients are an index of the relative soil drying rates. The $\bar{K}_r$ values were significantly greater than the $\bar{K}_i$ values at the early tassel and silking crop growth stages. The $\bar{K}_q$ values at the silking growth stage were significantly greater than the $\bar{K}_i$ values and significantly smaller than the $\bar{K}_r$ values. Figure 2 shows a plot of $\bar{K}_r$ minus $\bar{K}_i$ over the growing season and indicates that the relative difference in drying rate between the row and interrow increases as the crop develops, peaks at the time of grain filling, and then decreases as the canopy senesces.

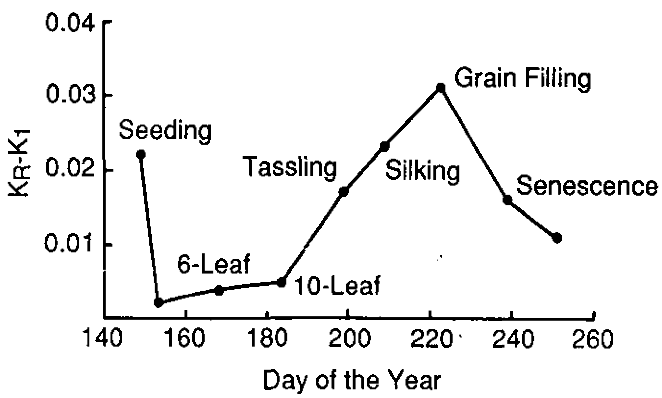

Figure 2. Difference in drying rate between the row and interrow (Kr-Ki) versus crop growth stage.

The average rate of soil water loss (mm/d) had the same spatial pattern as the drying coefficients (Table 2). The row position lost significantly more water than the quarter row and interrow position at the early tassel and silking crop growth stages. The systematic spatial pattern of drying rates (Table 2) would account for the differences in soil water content that occur through most of the growing season.

Soil water recharge from rainfall was also distributed systematically in space under the corn canopy. Measurements of soil water content taken immediately before and after an 8.2 mm rainfall event (silking stage) indicated an average increase of 10.2 mm, 7.9 mm and 5.6 mm of water storage for the row, quarter row, and interrow respectively (Table 3). The spatial differences in recharge were significant at the 0.01 probability level. The average recharge across all locations was 7.9 mm which was almost identical to the measured precipitation (8.2 mm). The increased recharge into the row area is attributed to leaf interception and subsequent stemflow. Similar spatial trends were observed for other rainfall events, however day 220 was the only event where measurements were made immediately before and after the rainfall. For example, an 8.4 mm rainfall event on day 233 resulted in an average soil water recharge of 9.2 mm and 5.8 mm for the row and interrow positions respectively.

Although more rain is directed into the row zone by the crop canopy (Table 3), the soil water content of the row position rarely exceeded that of the interrow position. This can be explained by the much more rapid decline of water content observed in the row compared to the interrow locations during drying cycles (Table 2). Thus, the drying periods created systematic spatial variations in soil-water content which were then attenuated during recharge periods. The net effect is a decrease in the spatial variance of soil-water content as the mean soil-water content increases during recharge, and an increase in spatial variance as the mean soil water content decreaes during drying. Thus, low soil-water contents in the middle of the growing season (full canopy) resulted in high coefficients of spatial variation of soil water content (Figure 3a).

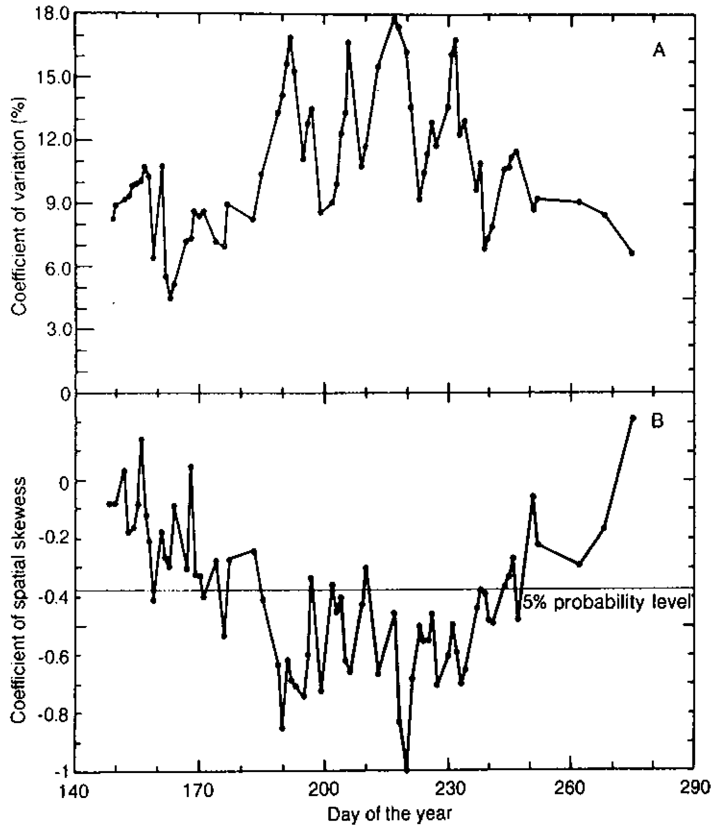

Figure 3. Coefficient of spatial variation (A), and coefficient of spatial skewness (B) of soil water content (0-0.2m) over the growing season.

The systematic change in the spatial pattern of soil-water content is illustrated in Figure 4, a smoothed plot of soil water content in time and space, for the drying period from day 199 to day 206. The spatial pattern at the beginning of the drying cycle (day 199) shows some row-interrow variations along with larger scale variations. As the drying progresses, the larger scale variations persist but significant row-interrow variations become superimposed on the original pattern, and the variance increases.

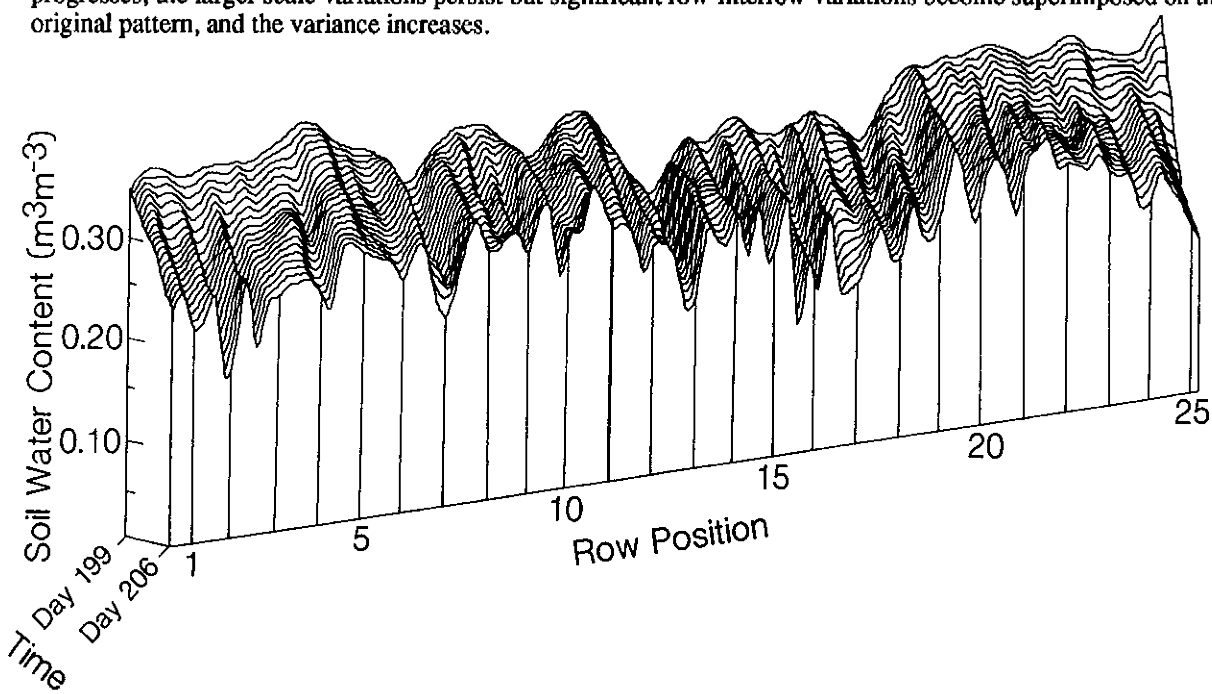

Figure 4. Plot of soil water content (0-0.2m) for one drying cycle (day 199 to day 206).

Other parameters of the spatial probability distribution function of soil-water content, in addition to the variance, were also affected by the canopy. A plot of the coefficient of spatial skewness versus time indicated that the spatial probability distribution function of soil water content became more negatively skewed as the canopy developed, then returned to near zero skew as the canopy died (Figure 3b). The coefficient of spatial skewness was not correlated to the mean soil water content and appeared to be related only to canopy growth and decay.

The relative sampling location also affected the temporal probability distribution function of soil water content. The mean temporal variance of the row positions was 34% higher than in the interrow positions (Table 4). The temporal skewness and kurtosis were not affected by spatial location. Thus, the higher temporal variance of the row positions is attributed to the more rapid drying and preferential recharge into the row compared with the interrow positions, which increased the magnitude of wetting and drying cycles.

CONCLUSIONS

This study indicates that careful consideration should be given to the placement of soil-water monitoring equipment in the plough layer and the selection of sampling sites under row crops for soil properties affected by soil-water content. For example, microbial biomass is very sensetive to changes in the soil-water regime, and has been shown to vary significantly between the row and interrow position.The temporal variances of soil water contents indicate the microbial environment in the interrow is much more stable in time than in the row position. The influence of the diferent temporal stabilities of soil-water content on microbial ecology and dynamics is unknown. The effect of the preferential recharge and drying of soil water in the row area on the modelling and prediction of solute transport through the unsaturated zone should also be studied.

TABLE 1 Mean soil water content (0-0.2m, m3/m3) at different crop growth stages and spatial locations

DAY OF YEAR	Crop growth stage	Soil water content(m3/m3) Row (θ_r)	Q-row (θ_q)	I-row (θ_i)	$\theta_i - \theta_r$
150	2-leaf	.256a	.273b	.280b	.024
162	5-leaf	.338a	.347a	.350a	.012
185	10-leaf	.274a	.280ab	.295b	.021
213	silking	.239a	.251ab	.273b	.034
241	grain fill	.338a	.345ab	.360b	.022
275	harvest	.375a	.376ab	.385b	.010

Values in the same row with the same letter are not significantly different at the 0.05 probability level.

TABLE 2 Mean drying coefficients and average water loss at different spatial locations for three drying cycles.

DRYING PERIOD	Crop growth stage	Drying coefficient (1/d) K_r	K_q	K_i	Average water loss (mm/d) Row	Q-row	I-row
day 168-172	6-7 leaf	.060a	.059a	.056a	3.7a	3.7a	3.4a
day 199-206	tassel	.059a	.051ab	.042b	3.2a	2.8b	2.2c
day 223-226	silking	.069a	.049b	.038c	4.1a	2.9b	2.4c

Values in the same row with the same letter are not significantly different at the 0.05 probability level.

TABLE 3 Mean soil water recharge from an 8.2 mm rainfall on day 220.

Sampling location	Soil water storage (mm)		
	1 h before rainfall, S_i	0.5 h after rainfall, S_f	recharge S_f-S_i
Row	54.2	64.4	10.2a
Q-row	52.4	60.3	7.9b
I-row	55.8	61.4	5.6c

Values in the same column with the same letters are not significantly different at the 0.05 probability level.

TABLE 4 Temporal statistical parameters of surface soil water content for different sampling locations.

Probe location	Temporal parameters	
	mean(m3/m3)	variance
Row	.286a	.205a
Q-row	.295b	.172b
I-row	.310c	.153b

Values in the same column with the same letter are not significantly different at the 0.05 probability level.

SEDIMENTARY CHARACTERISTICS OF A RECENTLY EMERGED ARCTIC LANDSCAPE, NORTHWESTERN FOXE BASIN

A. Webster, S. Sadura, and I.P. Martini

In July and August 1987, a sedimentological reconnaissance was carried out in northwest Foxe Basin, eastern Canadian Arctic. The operational base was the well-equipped Eastern Arctic Scientific Resource Centre, of the Ministry of Indian and Northern Affairs, located on Igloolik Island. This is part of ongoing research into characteristics and processes of recent and Quaternary cold environment sedimentation.

Northwestern Foxe Basin is underlain by variable bedrock, ranging from Paleozoic carbonates to Precambrian igneous and metamorphic rocks (quartzites, gneisses, schist, and others). During the Pleistocene, the region was covered by thick ice sheets. It was deglaciated approximately 6000 years ago and was subsequently submerged by glacial seas. Igloolik Island and much of the surrounding lands have emerged within the last 4000 years due to crustal response to glacial unloading. The Inuit have occupied the island since it first began to emerge from the sea over 3000 years ago, taking fish and marine mammals from the biologically rich shallow waters. The Inuit have always built their camps and communities close the sea where they could best butcher their catches of seal, walrus, and in the past, whale. Archaeological evidence consisting of sod huts, stone tent-rings, and animal remains litter the landscape, with the oldest evidence being found at the highest elevations. Radiocarbon dates from these sites provide data on the rate of isostatic uplift.

The present day environment is characterized by arctic climate. The sea is covered by pack ice for 9-10 months of the year, except at the large polynya east of Igloolik Island. During the short open-water season (generally August to late September), the sea is affected by drifting ice floes, mobilised by the ever changing winds. Thus, it is common for coasts to become iced-in several times each summer, as the winds change direction. The sea is microtidal (less than 1 m range), and storms occur during September. Continuous permafrost is present, and the active layer is typically 1-2 m thick. Sorted stripes and circles, gellifluction lobes, and frost-shattered scree deposits are the dominant permafrost features of the region.

The sediments of these emergent lands consist of angular pebbles and subrounded boulders, infrequent sand layers and minor silt deposits mostly related to thin, discontinuous tills. The landscapes of carbonate terrains are dominated by sequences of well-developed gravel beaches. With age of exposures the surficial beach pebbles undergo progressive comminution through frost-shattering and sharpening of edges by solution. A variety of soil containing reworked organic material. The lower part of the profile is gradational to a layered sand and pebble sedimentary deposit (10YR/4 to 5Y6/1 in colour). The base of the soil pit (depth 1-1.5 m) is marked by the permafrost table.

MEASUREMENT AND ESTIMATION OF CROP MICROCLIMATES FOR PEST MANAGEMENT

Zhang Yun and T.J. Gillespie

A knowledge of the duration of leaf wetness is a required input for several pest management schemes (e.g. tomatoes, onions, apples). The implementation of these schemes is sometimes hampered because measurements of wetness duration in the crop are not practical or convenient. We are therefore progressing toward a means of estimating crop wetness duration from measurements made outside the crop, at a nearby weather station.

Data were gathered at the Elora Research Station weather site, and in nearby corn and soybean fields during 1987. Good success at estimating dew duration from weather station data was achieved for these crops (e.g. Table 1). Further work will focus on estimating wetness persistence following rain.

***Table 1.** Observed wetting onset or ending, and wetting or drying estimated from weather station data, for corn and soybeans.*

Julian day	Crop	Obs. onset	Est. onset	Obs. ending	Est. ending
231-232	corn	21:30	21:30	08:30	08:30
	soybean	21:15	21:30	08:30	08:30
232-233	corn	19:30	19:00	08:00	08:30
	soybean	19:00	19:00	08:30	08:30
233-234	corn	19:45	19:30	08:30	08:30
	soybean	19:30	19:30	09:00	08:30

The method (Gillespie, 1987) promises to allow pest management that requires leaf wetness duration to be practised where in-crop sensors are not practical. Although the tests to date were done at a location where corn and soybeans were the conveniently available crops, the methods are generalizable to other crops.

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LAND MANAGEMENT

PLOWDOWN NITROGEN IN BARLEY AND CORN PRODUCTION

V.J. Alder and R.W. Sheard

Plowdown legumes are recommended as a N source in cereal and corn production yet little direct information exists on the contribution of N from various legumes. Likewise there are data suggesting the contribution to corn exceeds that to barley. Finally to maximize the conservation benefit of plowdown legumes it is preferable to not plow, hence does this management technique alter the availability of the N.

Red clover and alfalfa were established in 0.75 by 0.75m microplots in May, 1985. The legumes were labelled in situ with ^{15}N-urea on Sept.20, 1985. In May, 1986, the red clover and alfalfa were either incorporated into the plow layer or chemically killed and left on the surface. One plot of barley and of corn per replicate was fertilized with ^{15}N-labelled urea. Additional plots, producing barley and corn in 1985 and 1986, served as check treatments. Barley or corn were planted on May 12 and May 14, 1986, respectively. ^{15}N analysis was used to identify the quantity of nitrogen in the barley and corn which was obtained from the legumes or urea.

Table 1. The influence of nitrogen source and tillage on the yield of the total above and below ground biomass of barley and corn and the grain yield.

Tillage	Nitrogen Source	Barley Total Biomass	Barley Grain	Corn Total Biomass	Corn Grain
				(kg dry wt/ha)	
Yes	Urea	8000	3330	15050	5560
	Alfalfa	7160	2490	17300	6790
	Red Clover	8200	3170	16940	6350
	No Legume	6850	2510	7430	2810
No	Alfalfa	7270	2960	15300	5720
	Red Clover	7910	2890	13300	5230
	No Legume	5590	2100	6900	2770

Although there was no significant difference between the source of N or between tillage or no tillage the total biomass production of barley was increased by an average of 19% over no N input (Table 1). The grain yield of barley where N was supplied either as urea or legumes averaged 33% more than where legumes or urea were withheld.

Considerably greater biomass was produced by corn. The response of corn biomass production to some form of N input averaged 119% more than where none was supplied by urea or a legume. Likewise the incorporation of the legume residues increased grain production by 18% over the urea aplication whereas the no-till residues and urea were equal.

The incorporation of the residues from the plowdown legumes increased the average total N in barley by 9.6 kg N/ha (Table 2). Barley growing on soil containing red clover residues took up 13 kg/ha more N than from soil containing alfalfa whereas urea was intermediate in supplying N. While there was no difference between N sources for corn, the total N uptake by corn grown without residue-N or urea-N was 58% less than where they were added to the system. Leaving the residue on the surface produced corn containing 30% less N than where the residues were incorporated.

Labelling the legume residues and the urea with ^{15}N permitted a direct estimation of the uptake of N from the three sources. There was little difference in the amount of N taken up from the three sources by barley (Table 2). The legume sources, however, interacted with tillage to provide 5 kg/ha more N from alfalfa where they were left on the surface. Equal amounts of N were absorbed from the sources by corn except from no-till alfalfa which tended to be 44% lower than the average of the other sources.

The difference between the total N uptake and the N derived from the sources gave an estimate of the native soil N uptake (Table 2). Thirteen kg/ha less soil N was absorbed where barley was grown on soil containing alfalfa than where it contained red clover. Although the amount of native soil N absorbed by corn under no-till averaged 20% less than where residues or urea were incorporated, the average soil N uptake by corn receiving fertilizer or residue N was double that of corn without extra N. The application of a N source increased soil N uptake by 111% where incorporated and by 52% where they were not. The increased utilization of soil N by corn where fertilizer or legume N was applied is called the "priming effect". The priming effect played little or no role in contribution N to the production of barley.

The priming effect for corn is considered to be dependent upon the delayed N uptake by corn into mid-July and August. The measurement of the release of mineral N from the decomposing residues was characterized by an early delivery until mid-July with negligible release during the remainder of the cropping season (Fig.1). Early development of the barley resulted in a rapid depletion of the mineral N. The slower developing corn, however, resulted in an accumulation of mineral N in the soil into July. The longer residence time of the mineral N in the soil under corn is suggested as a casual factor of the enhanced priming effect observed with corn through stimulation of microbial populations.

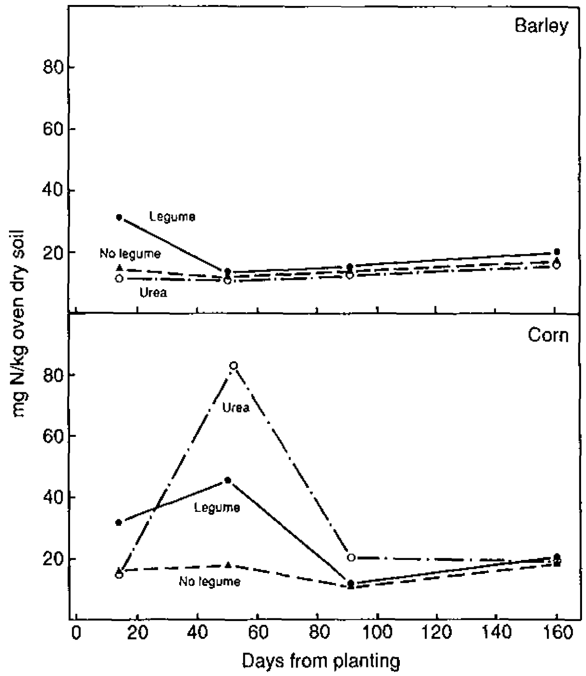


Figure 1. *The change in mineral nitrogen content of the soil with and without legume residues are fertilized with urea during the production of barley and corn.*

An average of one-third of the total N in the barley was obtained from the legumes or urea (Table 3). In contrast 25% of the total N in corn was obtained from the residues or urea.

Although urea was applied at 75 kg N/ha to barley and at 120 kg N/ha to corn, one-third of the fertilizer N was recovered by both species (Table 3). On the other hand the total input of red clover N was 233 kg/ha and the input of alfalfa N was 130 kg/ha from the residues. Nevertheless the recovery of the legume N by both barley and corn was remarkably similar. The recovery of alfalfa N averaged 21% in contrast to 12% for red clover, however, the recovery from no-till red clover tended to be low.

The priming effect observed with corn suggests the credits allowed in the N recommendation for legume plowdown should be greater for corn than for barley. The data from this experiment, and other subjective experiments, suggest that whereas a credit of 45 kg N/ha for plowdown legumes may be satisfactory for barley, the credit should be doubled to 90 kg N/ha for grain corn.

Table 2: *The amount of total nitrogen, soil nitrogen and urea, alfalfa and red clover nitrogen absorbed by barley and corn.*

	Nitrogen	Barley			Corn		
Tillage	Source	Total N	Source N	Soil N	Total N	Source N	Soil N
				(kg/ha)			
Yes	Urea	82	25	57	150	42	108
	Alfalfa	73	22	51	150	32	119
	Red Clover	95	28	67	161	39	121
	No Legum	55	-	-	55	-	55
No	Alfalfa	73	27	46	123	30	93
	Red Clover	77	21	55	95	24	86
	No Legume	45	-	45	59	-	59

Table 3: The proportion of total nitrogen in barley and corn which was obtained from urea or from alfalfa and red clover residues and the recovery of the nitrogen from the three sources.

Tillage	Nitrogen Source	Portion Total N From Source		Recovery of Applied N	
		Barley	Corn	Barley	Corn
			(%)		
yes	Urea	31	28	34	35
	Alfalfa	30	21	17	25
	Red Clover	30	24	12	17
No	Alfalfa	37	24	21	23
	Red Clover	28	26	9	10

THE EFFECT OF NITROGEN SOURCE AT DIFFERENT STAGES OF DEVELOPMENT ON THE GROWTH AND YIELD OF HYDROPONICALLY-GROWN CORN

K.G. Alexander and M.H. Miller

The effect of nitrogen source at different stages of development on the growth and yield of two hydroponically-grown corn hybrids has been studied for the past two years at the Cambridge Research Station. The two sources of nitrogen compared were nitrate and an ammonium/nitrate mixture (1:2.6). It has been hypothesized that an ammonium source of N may result in increased yields due to a decreased energy requirement for its assimilation as compared with nitrate. The source of nitrogen remained either constant throughout the entire season or was switched at anthesis. The total amount of nitrogen supplied was constant throughout the season. Four treatments were compared in 1986 while only three were used in 1987 as shown in Table 1.

Table 1: Hydroponic treatments used in N source comparison study.

Year	Trmt	Planting	Silking	Maturity
1986/1987	AN	NH_4^+/NO_3^- ⟶	⟶	⟶
1986/1987	N	NO_3^- ⟶	⟶	⟶
1986/1987	AN-N	NH_4^+/NO_3^- ⟶	NO_3^- ⟶	⟶
1986	N-AN	NO_3^- ⟶	NH_4^+/NO_3^- ⟶	⟶

The plants were grown in 22-litre white plastic pails filled with Turface as the rooting medium. The plants were grown two to a pail and arranged to give a population density of 90,000 plants per hectare. Approximately 750 ml of nutrient solution was added to each pail 2 to 4 times per day depending upon stage of growth.

The two hybrids, Pioneer 3925 and Pioneer 3949, responded differently to nitrogen source in 1986. Neither hybrid showed a differential response to nitrogen source prior to silking. After silking 3925 continued to show no differential response while 3949 showed a preference for a mixed N source during the period from silking to 4 weeks post silking as seen in Table 2.

In 1987 again no preference was shown towards source of N prior to silking (Figure 1). During the first 2 weeks after silking a preference for a mixed N source was found for 3949. The continued high growth rate of the AN-N treatment may have been due to the presence of some residual ammonium being made available for plant growth. During the next growth period, 2 weeks to 4 weeks post silking the preference for ammonium as a component of the nutrient solution was observed for both hybrids and was found significant at the $p = 0.05$ level (Table 3).

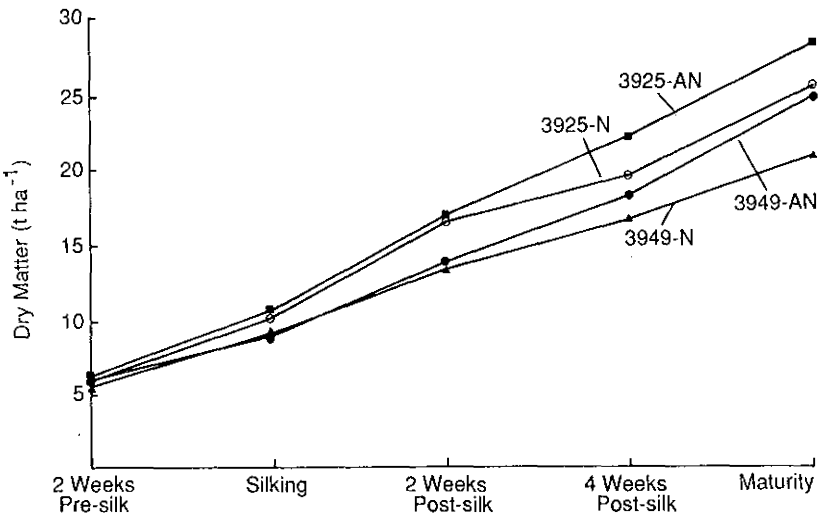


Figure 1. *Above ground dry matter of maize grown hydroponically with a NO_3^- -only (N) and as NH_4^+ + NO_3^- (AN) source of nitrogen.*

Summary

The period from 2 weeks to 4 weeks post silking appears to be one of the most crucial time periods in terms of source of N determining final yield. It was during this period that 3949 showed its preference for ammonium as a component of the N source for both 1986 and 1987. As well 3925 showed a similar preference in 1987. Why 3925 exhibited a preference in 1987 and not in 1986 is unclear but may be due to the exceptionally good growing conditions experienced during the 1987 season. The absence of a N source response prior to silking suggests that during this period the growth of corn is not limited by photoassimilate energy but by the rate of leaf growth and expansion.

Table 2: Growth rates from silking to 4 weeks post silking and final grain dry matter for 1986.

Hybrid	3925		3949	
Trmt	AGDM*	Grain D.M.	AGDM	Grain D.M
	kg ha $^{-1}$ d $^{-1}$	t ha $^{-1}$	kg ha $^{-1}$ d $^{-1}$	t ha $^{-1}$
AN	329	10.36	359	10.00
AN-N	328	11.16	310	10.44
N-AN	312	10.78	329	9.34
N	346	10.34	230	8.84
$LSD_{.05}$	103	0.88	103	0.88

*AGDM = Above Ground Dry Matter Growth Rate.

Table 3: Growth rates from 2 weeks post silking to 4 weeks post silking and final grain dry matter for 1987.

Hybrid	3925		3949	
Trmt	AGDM	Grain D.M.	AGDM	Grain D.M.
	kg ha $^{-1}$ d $^{-1}$	t ha $^{-1}$	kg ha $^{-1}$ d $^{-1}$	t ha $^{-1}$
AN	396	13.46	315	12.6
AN-N	352	12.59	310	11.84
N	234	11.99	232	10.71
$LSD_{.05}$	139	1.17	139	1.17

PROGRESS ON A N SOIL TEST

E.G. Beauchamp and R.G. Kachanoski

A simple, rapid, reliable N soil test method would greatly assist in predicting the fertilizer N requirement of a crop more accurately. Such a method would result in greater crop production profit as well as minimize N loss into the atmosphere or to the groundwater.

The general approach being followed is to first measure mineral N content of the soil profile (0-45 or 0-60 cm) in late May or early June in control (no N) plots. This measurement is related to the most economic rate (MER) of N fertilizer for a particular trial site. The MER value is obtained from a measurement of crop yield response to increasing N fertilizer levels.

After two years of study, the expected inverse relationship between soil profile mineral N content in late May or early June and MER of N for tomatoes has been disappointing. Some success has been obtained with potatoes but, as only four trials have been conducted, more data are needed to confirm the relationship. The most success has been obtained with corn. With results from several trials, a clear, inverse linear relationship has been obtained between soil profile mineral N measured in late May and MER of N fertilizer. It is interesting that the slopes of the linear relationships for 1986 and 1987 data are different.

As expected, the mineral N content in the soil profile generally increased exponentially during the late May/early June period. It is noteworthy that, with the corn trial results, the soil profile mineral N in late May could be used to predict fertilizer N requirements. This could provide more lead time for the application of fertilizer N to a corn crop if a N soil test were used. Further data will be obtained from small plot trials as well as from Conservation Tillage 2000 trials to examine the development of an acceptable soil test.

SOIL MOISTURE CONDITIONS IN POTATO FIELDS

D.M. Brown, G. Singh and I. van Wesenbeeck

Soil water content in the surface layers of potato fields show greater spatial variations after short drying periods than do fields seeded to corn, soybean and cereal crops, since potatoes are planted in ridged (hill) rows. In order to schedule irrigation using soil water budgeting procedures, it is necessary to know how much water is lost through evaporation from the hills and hollows of the ridged surface in potato fields. To calibrate and validate the soil water budget (see 1986 LRS Annual Report, p. 58) in models like SIMPOY (SIMulation of POtato Yields) the differences in surface soil moisture across potato rows is needed.

Measurements were made on a potato farm near Alliston in 1987 and in a cultivar drought tolerance experiment at the Cambridge Research Station in 1986 and 1987. The Time Domain Reflectometry (TDR) method was used to measure volumetric soil water content. TDR probes were permanently placed in a transect perpendicular to the plant rows. Probes 20 cm in length were used in 1986 and 15 cm and 30 cm probes were used in 1987. A Textronic 1502 cable tester was used to determine the dielectric constant of the soil which in turn was used to infer values of volumetric soil water content.

In 1986, readings were taken on four dates between early July and mid-August from a set of 24 probes placed in a Lisbon sandy loam to a depth of 20 cm. In each of two replications of the experiment, probes were placed on top of the hill, in the hollow, and on the sides of the hill (halfway between the top of the hill and the hollow) in a transect spanning 6 potato rows. Averages of these readings showed that moisture content in the centre of the top of hills was about one-third of that in the 20 cm layer below the bottom of the hollow, and the sides of the hills contained about twice as much moisture as the top of the hill but less than the hollow (Fig. 1).

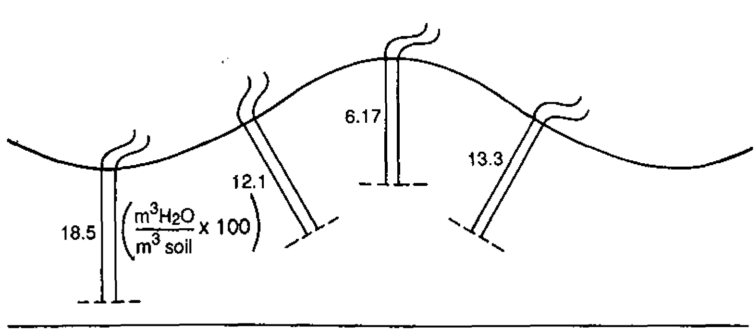
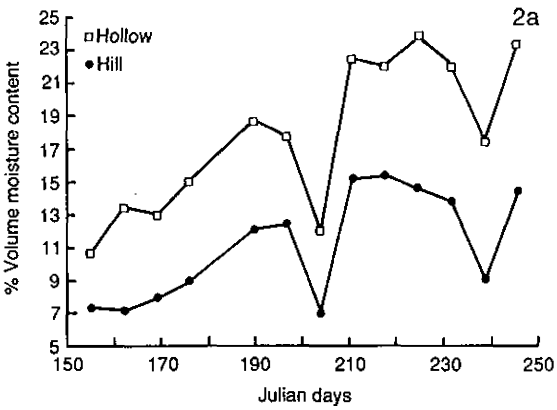


***Figure 1.** Placement of TDR probes, and average volumetric water content (m3/m3) at each location.*



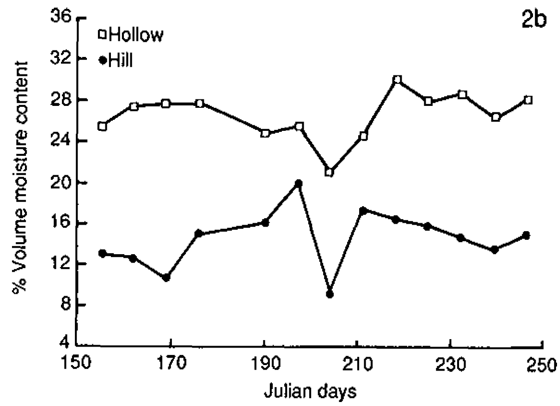


Figure 2. Volumetric water content (%) for the hill and hollow positions for the 0-5 cm layer (A), and the 5-15 cm layer (B)

In 1987, weekly measurements were made from early June to early September with 15 cm length probes placed in row positions similar to those in 1986 and 30 cm probes in the tops and hollows of the rows. The 15 cm probes were used to measure soil moisture in the 0-15 cm layer, and also in the 0-5 cm layer by placing them at an angle to the surface. The difference between these two sets of readings was used to determine the 5-15 cm layer moisture content, and the difference between the 0-15 and 0-30 cm readings was used to determine the 15-30 cm layer moisture content. The moisture content determined from measurements made in an Alliston fine sandy loam near Alliston are shown in Figs. 2a and 2b for the hollow and hill positions. In the 0 to 5 cm layer the difference in moisture content between the hills and hollows averaged for the 13 readings was 7.1% by volume, in the 5 to 15 cm layer 8.8%, and in the 15 to 30 cm layer 13% with the hollow always having greater water content.

It is not this average difference that is important for water budget procedures, but the differences that exist on individual days for each layer. For example, on day 166 (June 18) the difference in soil water content between hill and hollow in the 0-5 cm layer was only 5% whereas in the 5 to 15 cm layer the difference was 17%. The SIMPOY model is being calibrated to account for these differences.

TANZANIA-CANADA AGROGEOLOGY PROJECT - END OF FIRST PHASE

W. Chesworth, P. van Straaten, P. Smith and D. Crabtree

Agriculture and forestry exploit the ability of soil to provide nutrients to a crop. The farmer and the forester for the most part treat the soil as a nutrient mine. Unlike more familiar mines however, it is a renewable resource at least while the earth remains an active planet. Tectonic, igneous and sedimentary processes combine in the internal and external geochemical cycles, to add fresh nutrient-laden rock continually to the biosphere. If this were not so, the land surface of the earth would long ago have been reduced to a uniform low fertility.

Unfortunately, the rate of renewal by natural geological processes is slower by up to two orders of magnitude, than the rates at which farmers exhaust the soil. Consequently an important part of the historical evolution of farming has involved the development of practices that enable the soil to recover its fertility after cropping. These range from low-input methods such as shifting cultivation to the high-input techniques that support monoculture in modern industrial farming. No technique has been entirely successful, though in geologically favoured environments, the Nile Valley and northern China for example, thousands of years of continuous cultivation have been achieved. However even in the favoured cases problems such as salinisation and soil erosion arise and the history of cultivating the soil is perhaps more a history of crisis control than of unadulterated progress.

The process of weathering is crucial to the fertilization of soil. The principal reaction, or complex of reactions, is a massive overtitration of bases contained in and on the land surface, against aqueous solutions of acids obtained from atmospheric and biospheric sources. The result is a release of nutrient elements from the minerals of rock and soil and, at least in humid climates, the gradual acidification of the weathering regime towards relatively infertile compositions buffered by phases in the system SiO_2-Al_2O_3-Fe_2O_3 - organic acids - CO_2-H_2O. Generally, the release rates are not fast enough to support continued cropping so that the weathering of ordinary minerals and rocks cannot be expected to sustain a crop. Yet in certain environments, the humid tropics for example, and with certain materials (e.g. apatite in acid soils), natural minerals do indeed weather fast enough for the agronomist's purposes. In most cases however, a farmer relies upon materials more soluble than the common minerals to replenish the nutrients of arable land. Even so everything the plant needs except N, H_2O and CO_2 is ultimately derivable from rocks of one kind or another.

The conversion of geological raw materials into more soluble fertilizers is energy intensive and the eventual price of the fertilizer is proportionately high. Unless credit (as in the Cameroons) or subsidies (as in Zimbabwe) are available, third world farmers cannot afford the fertilizers that developed world agriculturalists rely upon. Thus, to have a truly self sustaining agriculture in the developing word cheaper inputs than those that support industrialised farming are needed. In terms of fertilizer, this means finding locally available raw materials that require little or no processing. This is the fundamental idea behind the Tanzania-Canada Agrogeology Project undertaken by the University of Guelph in Canada, with the Geological Survey of Tanzania and the Sokoine Agricultural University and Uyole Agriculture Centre in Tanzania. Funding is provided by I.D.R.C., Ottawa and by the Tanzanian Government. However there is more to the project than simply finding fertilizer raw materials. Our initial target area, the Mbeya region, just north of Lake Nyasa, is one of the most important agricultural regions of Tanzania. In this region the soils are mostly of inceptisolic, oxisolic and ultisolic orders.

The first phase of three years duration ended on 31 December 1987. During that time the following chemical and physical problems in the soils of the Mbeya region were defined.

1. Chemical problems:
   - (a) High acidity
   - (b) Low fertility
   - (c) Elemental toxicities (Al and Mn in particular)
   - (d) Micronutrient deficiencies (e.g. Cu and Zn)
2. Physical problems:
   - (a) Sheet and gully erosion
   - (b) Water conservation

Solutions to all of these problems are being sought and most of the effort of the second phase will go into this work. So far we have been successful in four areas. First and foremost we have found a number of locally available phosphatic rocks that have been successfully used directly on the more acid soils. Second we have located zeolitic materials that can be used to conserve the ammonium nitrogen of manures, and when added to apatite, cause the latter to break down more readily than otherwise. Third, large volumes of liming materials have been identified and are being tested as a means of reducing acidity and related toxicity problems. Last we have introduced a technique of rock mulching, originating in the Canary Islands, as a means of cutting water losses by as much as 60%. This utilises the vast deposits of volcanic ash and scoria of the region, materials that our greenhouse trials also show have great potential as a very cheap source of plant nutrients.

The following is a brief summary of our work during the final year of the first phase.

GEOLOGICAL FIELD WORK

The main targets of the third year's reconnaissance surveys were:

1. Morogoro Region:
   - Zizi,
   - Maji ya Weta,
   - Wigu Hill,
2. Mbeya Region:
   - Nachendezwaya,
   - Mbozi Ring Complex.

These five target areas were studied mainly for their phosphate potential. We also began semi-detailed follow-up work at the Panda Hill and Ngualla phosphate prospects. More detailed work will be carried out on the two latter prospects during phase II of the project.

Additionally, the geochemical sampling on a reconnaissance base was conducted for the Kigugwe copper prospect (Mbeya Region, at Kwekivu vermiculite showing (Handeni district at Kasulu-Kobondo (for potential sedimentary phosphate), and at the tailing dumps of the Mwadini diamond mine (Shinyanga region).

The main outcome of this year's field season is the delineation of sizeable high grade (> 25% P_2O_5) primary phosphates at the Ngualla carbonatite. At least 3 zones of apatite-magnetite veins, each several hundred metres long and 10-20 m wide, could be traced in the eastern and northeastern zone of the Ngualla carbonatite complex. The phosphate bearing residual and transported soils (several metres thick and containing 12-20% P_2O_5) which were discovered in 1986 seem to be derived from these primary sources.

All three phosphate targets in the Morogoro Region and the two remaining targets in the Mbeya region turned out to be of low to very low grade in regard to phosphate. However, the Wigu Hill carbonatite of the Morogoro District was confirmed to have a high potential for Rare Earths, analysing 12.06 and 9.34% LREO.

Lithogeochemical sampling for micronutrient resources confirmed the extensive stratabound low grade copper prospect of Kigugwe (1.3% Cu). Preliminary agronomic testing of the malachite/azurite bearing shales indicate that this locally available copper resource could be used to partially substitute some of the imported copper fertilizers, used on Cu-deficient soils in Mbeya District.

SOILS FIELD WORK

The Tanzanian soil scientists from Morogoro and Uyole chose sites in those regions, for field trials using materials provided by the geologists. The sites chosen for the study differed widely in agro-ecological characteristics. This is important in order to generate data representative of a wide range of existing conditions. The properties of the soils used in the study are given in Table 1. They belong to four soil orders (Soil Taxonomy System) namely Ultisols, Inceptisols and Entisols. The important properties in relation to phosphate rock (PR) studies are pH, available P and exchangeable Ca. The ranges for these are as follows:

pH: 4.6 - 6.6; available P: 1.8 - 21.6 ppm and exchangeable Ca: 0.9 - 5.8 me/100 g. Most of the P levels are low, the problem being particularly severe in Ihanda and Chivanjee soils. Mafiga 2 soils had an available P level close to the critical value of 25 ppm reported by Singh et al. (1977). Soils with low P levels (<25 ppm) are expected to respond to P application.

Four of the soils namely Chivanjee, Magadu, Mzumbe and Ilindi are strongly acidic and contain exchangeable aluminum. These properties together with low Ca may limit productivity. The rest of the soils are only moderately acid and problems related to acidity are not expected to limit their productivity.

Data on the type of clay minerals and micronutrient contents are given in Table 2. The dominant clay minerals in most of the soils is kaolinite and/or halloysite. Illite also exists in some soils but to a much less degree.

Of the few soils where the micronutrient data are available, low amounts of Cu were observed in Ilindi, Ihanda and Uyole. Generally a large proportion (>60%) of the soils from Mbeya district are known to be deficient in Cu (Kamasho et al. (1982). Available Zn extracted with diethylene-triamine-penta-cetale-DIPA) contents of soils form Morogoro were close to the value of 0.85 ppm suggested by Nzabhayanga and Mnkeni (1985) to be the critical level for deficiency for these soils.

It is thus evident from the above data that the commonest problem limiting productivity, apart form N, is phosphorus deficiency, followed by acidity, and Cu and Zn deficiencies. Problems of soil erosion and for Morogoro and Mbozi districts moisture stress are also considered important.

Table 3 gives the properties of the phosphate rocks evaluated. Panda concentrate was obtained from Panda PR by washing twice with water. Minjingu PR is a sedimentary phosphate whereas the rest are igneous ones. The total P_2O_5 content varied form 8.3 to 34.0% while the ammonium citrate (pH 7) soluble P_2O_5 varied from 0.11 for Mbalizi PR to 2.86 for Minjingu PR. Minjingu PR is of high grade (high P_2O_5) and the amount of P_2O_5 soluble in neutral ammonium citrate is comparable to values reported by Leon et al. (1986) for very reactive PRs (North Carolina and Arad) suggesting that it may behave similarly. Mbalizi and Njelenje PRs have much lower solubilities in neutral ammonium citrate, a characteristic of igneous PRs.

The calcium oxide content varied from 25.5 to 47.6%. For two PRs, the neutralizing values were also determined and found to be 79.5% for Mbalizi and 2.5% for Njelenje. This suggests that Mbalizi PR could be an effective liming material.

EXPERIMENTAL WORK

The above rocks and soils are being used in a series of pot and field trials conducted at Morogoro and Mbeya. Early results show clearly that PR can be used directly on ultisolic soils in the two regions. However the agronomic assesment of agricultural raw materials with the monitoring of residual effects, requires several seasons' work before a reasonable set of recommendations can be derived for farm use.

Table.1. Properties of the soils used in the different studies.

Location	Soil Order	pH H_2O	O.C (%)	Bray1-P (ppm)	Exchangeable Cation Ca	Mg	K	Na	Al	C.E.C	Clay content
m.e./100g											
Morogoro											
*Magadu 1		6.2	1.5	10.6	5.8	5.2	1.5	0.36	-	19.8	
*Magadu 2	Ultisol	4.6	1.2	5.6	1.6	1.3	0.7	0.04	1.4	9.1	23
*Magadu 3	2nd maize expt						.				19
Mzumbe	Oxisol	5.2		6.3	1.3	1.0	0.6	3.30	1.1	4.8	
Mafiga 1	Ultisol	6.6		6.1	4.5	2.1	0.3	.07	0	7.1	
Mafiga 2	Entisol	6.2		21.6	3.3	2.6	0.5	0.31	0	6.9	
Mbeya											
Chivanjee	Oxiso	4.8	n.d	1.8	0.9	0.8	n.d	n.d.	1.5	29.0	58
Ilindi	Inceptisol	5.3	2.2	5.6	0.9	2.1	0.42	0.16	0.5	28.0	35
Ihanda	Ultisols	5.6	1.7	3.5	2.4	2.5	0.84	0.24	0	19.0	55
Magamba	Inceptiso	5.7	1.5	4.2	2.3	2.3	0.72	0.19	0	17.0	27
Mitalula	Oxisol	5.8	1.4	9.1	2.2	2.4	0.72	0.19	0	18.5	26
Uyole	Inceptisol										

n.d. = not determined

*Magadu 1 = pasture experiment; Magadu 2 = maize and bean experiment; Magadu 3 = second maize experiment.

Table 2. Mineralogy and micronutrient contents of the soils used in the different experiments.

Micronutrient Content Location	Dominant Clay Mineral	Micronutrient Content Cu (ppm) Total	Cu (ppm) Available	Zn (ppm) Total	Zn (ppm) Available	Mn %	Fe %
Morogoro							
Magadu 1	Kaolinite , *some illite			---			
Magadu 2	Kaolinite , +some illite			0.7[3]			
Magadu 3				---			
Mzumbe	*Kaolinite + Al and Fe oxyhydroxides			0.9[3]			
Mafiga 1	*Kaolinite + Al and Fe oxyhydroxides			0.8[3]			
Mafiga 2	*Kaolinite and hydrous mica			---			
Mbeya							
Chivaujee-		34.6[1]	1.4	--	--	- ---	---
IlindiKaolinite		2.4	---	78		0.11	6.7
Ihanda Kaolinite		4.8		83		0.31	10.1
Mbimba	*Kaolinite/Halloysite	15.0[1]	1.3	---	----	---	----
Mitalula		---	---	---	----	----	----
Uyole	*Halloysite + Al & Fe-oxyhydroxides	8.1[1]	0.5[2]	4.0	----	---	

*From Moberg (1981)

1. Mbonika and Uriyo (1984)
2. J.A. Kamasho (1980) (M.Sc. Thesis University of Dar-es-Salaam)
3. Nzabhayanga and Minkemi (1985)

Table 3. Chemical properties of phosphate rocks

Phosphate	Total	P_2O_5 Nac	CaO	MgO	Na_2O	K_2O %	MnO	SiO	Al_2O_3	Fe_2O_3	N.V.
Minjingu	34.0	2.86	46.4	3.4	0.84	1.4	0.04	10.4	2.3	1.0	n.d.
Njelenje	17.8	0.23	25.5	0.16	0.76	5.5	0.36	24.8	6.0	14.	2.5
Mbalizi*	8.3	0.11	47.6	1.26	0.10	0.17	0.22.	2.4	0.4	0.7	9.3
Panda	10.4	----	20.1	1.2	0.3	1.5	0.4	28.2	6.0	23.5	n.d.
Panda Conc.	18.9		33.2	1.4	0.3	1.5	0.2	17.2	3.8	17.6	n.d.

n.d.-not determined

*Mbalizi PR also refered to as Mbalizi carbonatite

NAC - refers to neutral ammonium citrate soluble P_2O_5

N.V. - neutraling value

THE NEXT PHASE

In any future work the main objective remains the same: to increase the food producing capacity of selected Tanzanian soils using locally, available geological materials in such a way that traditional husbandry practices are not disrupted. Specific activities written into our second phase proposal to IDRC are:

a) to evaluate, in detail, the geological resources identified in the first phase that were found to have agronomic potential, with respect to mineable tonnage and grades;

b) to develop simple physical beneficiation procedures for the Panda Hill phosphate deposit and to produce sufficient material for agronomic evaluation;

c) to continue to search for new fertilizer raw materials and their characterization;

d) to monitor possible harmful trace element buildup in the soils as a result of the application of the geological materials;

e) to develop new agromineral exploration models for general use in Eastern and Southern Africa and other areas with a similar geological settings;

f) to provide the geotechnical expertise necessary for the water conservation experiment using rock mulch;

g) to continue the agronomic evaluation of the geological fertilizer raw materials by glasshouse and field trials. Particularly important here is the assessment of residual effects in field experiments already in progress;

h) to continue assessment of soil fertility problems particularly P deficiency, Cu deficiency, soil acidity and related problems of metal toxicity and P fixation;

i) to investigate rock mulching as a means of soil water conservation particularly with perennial crops;

j) to survey existing farming practices regarding soil and fertilizer management;

k) to assess the economic feasibility of using the agronomically effective geological materials identified in the project.

Tangible results arising from this are:

a) the authorities in the Mbeya region will be provided with maps and other documentation detailing soil problems of the area investigated and locally available geological resources with agronomic potential;

b) for agronomic testing, sufficient apatite concentrates will be produced from the Panda Hill deposit, beneficiated by simple physical means;

c) a demonstration, for extension purposes, will be carried out of the successful application of geological materials and techniques in increasing food production in Mbeya region;

d) an initial assessment will be made o the costs and benefits to the local farmer of using geological amendments and techniques to improve food productivity.

Finally, we stress the following socio-economic aspects and benefit:

a) this project addresses the two major fertilizer problems facing the local, small farmer in Tanzania. One is the high cost of commercial produced fertilizer and the second is availability of same.

b) Approximately 140,000 tons of fertilizer is currently used per year in Tanzania. 40,000 tons of this is imported and even the remaining 100,000 tons that is produced within the country has substantial inputs of imported raw materials. The demand and needs far exceed these levels of availability.

c)Transportation problems aggravate the availability of fertilizers particularly in remote areas.

d) Another potential benefit of this approach is the creation of jobs in connection with the small-scale mining and processing of the geological materials.

e) Thus, the project should lead to increased food production, import substitution and hence foreign exchange savings, and development of local industries.

Looking further afield, the exploration and application methodologies we are developing are directly applicable to other parts of Tanzania and to much of the neighbouring regions of East Africa. The similar geological structures encountered in Kenya, Uganda, Ethiopia, Burundi and Malawi make these countries ideal for a direct transfer of the methods developed in Tanzania. In fact, with very little modification they can be applied to other parts of the third world.

MICROCLIMATIC INFLUENCE ON WATER STATUS OF DEAD PLANT TISSUES

M. Kalliomaki and T.J. Gillespie

Knowledge of the influence of microclimate on the water status of dead plant tissue is important to understanding the function of crop debris in reduced tillage systems. The decay of the tissue and its contribution to pest pressures both involve organisms whose activity depends on the tissue water status.

A controlled-environment study (Kalliomaki, 1987) of the relationships between water content, water potential and resistance to water gain or loss at various relative humidities has been completed for dead winter wheat tissue. The straw studied was placed in the field in May, then sampled in July and in the following May. Water uptake and loss were both studied for the July-sampled tissue, and no significant hysteresis in the water potential versus water content relationship could be detected. Only the water loss characteristics were studied for the May-sampled tissue. They did not differ significantly from the water loss data for the July-sampled tissue, despite the longer field exposure for the May samples. Power law relationships between tissue water content and water potential were developed. The resistance of the tissue to water loss was also determined, and did show a significant decrease after overwintering in the field.

Researchers studying the activity of organisms living in crop debris can measure the tissue water content gravimetrically, but field water potential measurements are rare because they are very difficult to perform. Organism activity, however, is most likely to be controlled by water potential. The data obtained thus far in this project provide a new link from the more easily measured or modelled water content, to the required information on water potential.

The project will now progress to examine field observations of microclimate and the water status of wheat debris on the soil surface.

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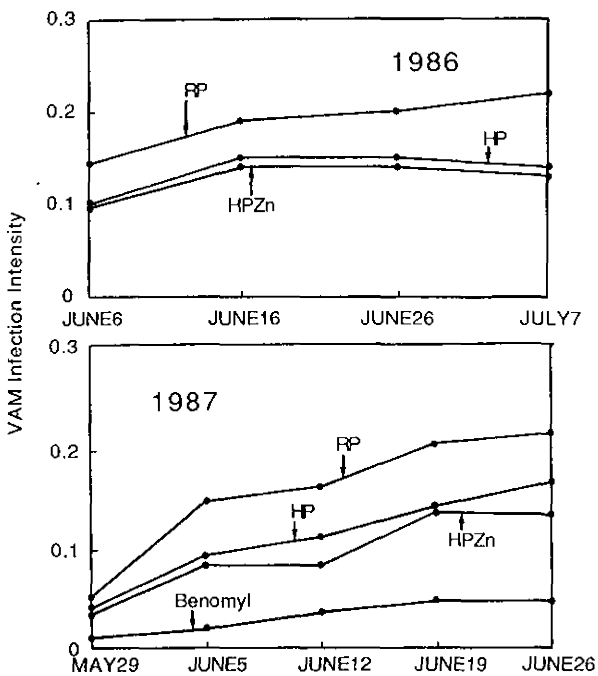
THE ROLE OF VA MYCORRHIZAE IN THE ABSORPTION OF P AND ZN BY MAIZE (ZEA MAYS L.) IN FIELD AND GROWTH CHAMBER EXPERIMENTS

S. Lu and M. H. Miller

Two years of field experiments and one growth chamber experiment were conducted to determine the role of VA mycorrhizae (VAM) in P and Zn absorption as well as in the P-Zn interaction. The pattern of development of VA mycorrhizae in the early growth stages of field-grown maize (Zea mays L.) plants was also investigated.



The field experiments were conducted at Elora Research Station and consisted of three fertility treatments, recommended phosphorus (RP), high phosphorus (HP) and HP plus zinc (HPZn). In 1987, the fungicide, benomyl, was used to reduce mycorrhizal infection on small areas within the plots. Soil from the RP and HP plots was used in the growth chamber experiment; Zn fertilizer was added to those soils to also have treatments of RPZn and HPZn. Benomyl was used to eliminate mycorrhizae in half the pots of each fertilizer treatment.

Mycorrhizal infection intensity developed rapidly in the field in both 1986 and 1987 (Fig 1). Proportion of the root length infected was closely related to infection intensity. In the field experiment of 1987, 20% of the roots were colonized by VAM in RP soil just three weeks after sowing and after 40 days, about 50% of roots were infected.

Figure 1. VA mycorrhizal infection intensity in 1986 and 1987 field experiment.

The HP treatment significantly reduced VAM infection intensity compared to the RP treatment in the field (Fig 1). There were no significant differences in the mycorrhizal infection intensity between HP and HPZn treatment in both years (Fig 1). In 1987, mycorrhizal infection intensity was markedly reduced with benomyl (Fig 1).

The HP treatment significantly increased the shoot P concentration compared to the RP treatment in both 1986 and 1987. Benomyl treatment resulted in significantly lower shoot P concentration in the RP soil in 1987, but did not affect shoot P concentration in the HP treatment (Fig 2). Purple leaves, indicating P deficiency, were observed in several benomyl plots of the RP treatment in the 1987 field experiment. Benomyl decreased mycorrhizal infection, shoot dry matter and shoot P concentration in the RP soil, therefore it may be concluded that VAM are involved in P absorption and plant growth in this soil. In the HP soil, benomyl did not affect shoot P concentration although the VAM infection intensity and shoot dry weight were significantly reduced by benomyl; therefore, there was no evidence to conclude that mycorrhizae were important for P absorption in the HP soil.

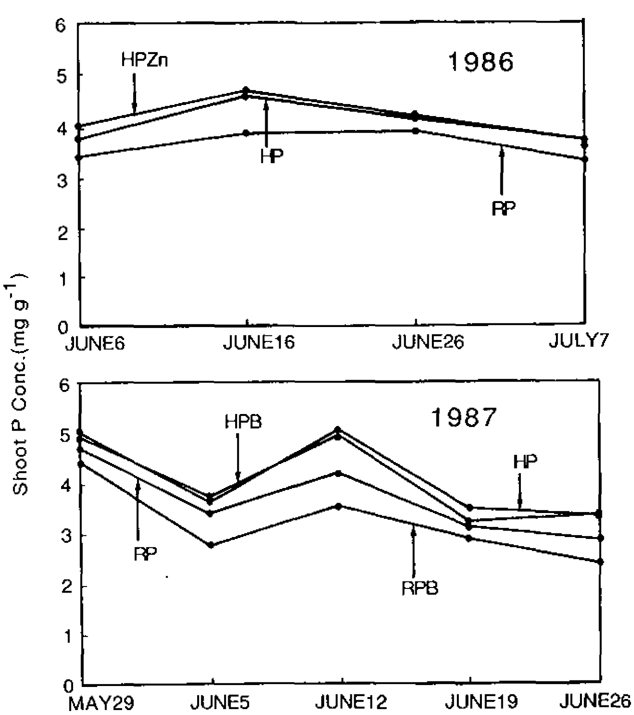


Figure 2. Shoot P concentrations in 1986 and 1987 field experiment.

Benomyl eliminated mycorrhizal infection in all fertility treatments in the growth chamber experiment. The HP treatment significantly reduced mycorrhizal infection. The addition of Zn significantly increased the mycorrhizal infection only on RP soil (Table 1). The shoot P concentration was reduced by benomyl in both RP and HP treatment, but the effect was significant only in the HP treatment (Table 1). In spite of the high level of phosphorus in the soil, the shoot P concentration in the HP treatment was very low. There was less mycorrhizal infection and lower shoot P concentration and shoot dry matter with benomyl in both the HP and RP soils, and hence it can be concluded that mycorrhizae were important for P absorption in both soils when the plant P concentration was very low.

Table 1. VAM infection, shoot dry matter and shoot P Concentration in growth chamber experiment

Treatment	VAM Infection Intensity	Shoot D.W	Shoot P Conc.
		g/pot	mg/g
RP*	0.057	1.40	1.16
RPB	0	1.21	1.14
RPZn	0.076	1.47	1.19
RPZnB	0	1.28	1.15
HP	0.03	2.35	1.39
HPB	0	1.88	1.25
HPZn	0.032	2.87	1.36
HPZnB	0	2.28	1.26

* RP, recommended phosphorus; HP, high phosphorus;
Zn, Zn application; B, benomyl.

The shoot Zn concentration was not affected by benomyl in either the growth chamber or field experiments, although the shoot dry matter was decreased by benomyl. Therefore, there was no evidence that mycorrhizae were important for Zn absorption.

Since there was no evidence of a P-Zn interaction in these experiments, no conclusion can be drawn on the importance of mycorrhizae in this interaction.

Due to the small plot size, it was not possible to get the final yield on the benomyl plots in 1987. Grain yield on the HP treatment was 7.78 t ha^{-1} in 1986 and 10.69 t ha^{-1} in 1987 while the corresponding yields in the RP treatment were 7.07 t ha^{-1} and 9.46 t ha^{-1} respectively, indicating that phosphorus was limiting in the RP soil. It has been shown that P concentration in maize plants prior to the 6-leaf stage significantly influences grain yield. Mycorrhizae increased phosphorus absorption in the early growth stage in the RP soil, therefore it is suggested that mycorrhizae contributed to the final grain yield of the crop fertilized at recommended rates.

SLOW RATE INFILTRATION LAND TREATMENT AND RECIRCULATION OF LANDFILL LEACHATE IN ONTARIO

R.A. McBride

Introduction

Slow Rate Infiltration Land Treatment

Land treatment systems are designed to circulate wastewater back into the soil-vegetation ecosystem in such a way that the maximum degree of renovation and attenuation of contaminants is achieved before the effluent re-enters the hydrologic cycle as deep drainage. The ecosystem thus acts as a "living filter" in effecting both physico-chemical and biological decontamination, with soil water recharge and plant nutrient supply being ancillary benefits.

Land treatment systems can be divided into three main types according to the mode and rate of wastewater application; slow rate infiltration, rapid rate infiltration and overland flow. Each is characterized by a unique hydraulic loading rate and set of ecosystem component requirements to achieve optimum wastewater treatment. The slow rate infiltration method makes the best use of the intrinsic ecosystem attenuation capacity:

1) by maintaining an aerobic soil environment, maximizing evapotranspirational losses and minimizing deep percolation (i.e. unlike the rapid rate infiltration method) and,
2) by normally eliminating the need for recollection and possibly final polishing treatment before discharge into water courses (i.e. unlike the overland flow method).

Disposal of landfill leachate on land is not widespread in North America. The practice is, however, widely used in the United Kingdom where the common procedure is to use specially prepared grass plots with underlying artificial tile drainage to intercept deep percolation and monitor effluent quality before discharging into surface water systems. Landfill leachate generally contains many essential macro- and micronutrients and would thus seem to have a good potential for renovation through ecological systems.

Several obstacles do exist, particularly under Ontario climatic conditions, to its widespread adoption. Firstly, it is difficult for this to be a final solution when conventional land application techniques (e.g. spraying) are impracticable during the winter months. Similarly, the sizeable surplus of precipitation over potential evapotranspiration on an annual basis in this province increases the risk of excessive hydraulic loading and waterlogging in the application area, with resulting adverse effects on vegetative vigour and survival. And finally, excess concentrations of certain elements (e.g iron) can have a significant phytotoxic effect on vegetation. If present in sufficient concentrations in the leachate, heavy metals can also accumulate in plant biomass thus precluding treatment in agricultural ecosystems. The phytotoxicity problem has been averted in parts of the southern United States and the U.K. by land treating leachate during the vegetatively dormant months of October to April.

Landfill Recirculation

Recirculation of leachate through the landfilled refuse has been recognized as a method of effecting partial leachate treatment and control of ground and surface water pollution associated with MSW (municipal solid waste) landfills. Largely pilot-scale research has shown three advantages to implementing recirculation to complement a primary treatment option (e.g. land treatment, aerated lagoon). Firstly, recirculation can be used as a means of storage if the primary treatment system malfunctions or volumes temporarily exceed the system's capacity. If properly capped, the refuse will remain unsaturated and will have a large storage capacity. A subsurface application network would also allow for winter storage, since volumes would be greatly curtailed relative to the spring and fall season. Secondly, this practice can significantly reduce the volume of leachate to be handled by the primary treatment system through evapotranspirative losses (i.e. 30 to 35% volume reduction). And finally, recycling leachate has been shown to accelerate landfill stabilization. By establishing a more optimum refuse moisture content, microbial activity is enhanced and a more anoxic environment is created due to increased gas evolution. The landfill itself thus acts as an "anaerobic filter" and substantially lowers the leachate BOD and suspended organic content. The overall result is a lower strength leachate which is likely to be more suitable for adjacent land treatment than the unrecirculated wastewater. The principal disadvantage is the increased hydraulic loading of the landfill which augments the potential for ground water contamination if the refuse cell is not double lined. Nevertheless, by reducing the volume and strength of the leachate, landfill recirculation can be viewed as an effective pretreatment step, particularly if it precedes slow rate infiltration land treatment.

Study Objectives

This is a 3-year research study (1987-1990) which will yield conclusions and recommendations on specific site conditions conducive to leachate land treatment/recirculation networks. The working objectives are as follows:

1. to evaluate slow rate infiltration land treatment of MSW leachate in forest or grassland ecosystems using alternative land application techniques as a practicable economic, environmentally-sound and long-term solution to landfill seepage occurrences under Ontario biophysical and climatic conditions.
2. to evaluate recirculation of leachate to the landfill surface as a partial on-site treatment method under Ontario climatic conditions.
3. to place the technical findings of this study within the context of the land use planning for wastewater treatment and disposal.

Experimental Procedures

Slow Rate Infiltration

The first year of the study (1987-88) has been largely devoted to experimental site selection, acquisition of the necessary approvals, design and establishment of pilot-scale installations and baseline inventories and measurements for use in subsequent monitoring of the effects of perturbation experiments in years 2 and 3 (1988-89, 1989-90). Sites selected and approved for installation of land treatment plots and irrigation initiation in 1988 are the Essex County Sanitary Landfill No. 2 near Leamington (one unwooded installation) and the Hamilton-Wentworth Regional Landfill in Glanbrook Township (one wooded and one grassland installation).

Each facility consists of three replicate blocks (randomized). Three slow rate infiltration methods will be used at three leachate application rates (i.e. 3.5, 7.0 and 14.0 mmd^{-1}), although the irrigation program will be modified in accordance with daily ambient weather conditions (e.g. precipitation events). The experimental design includes both water-irrigated and rain-fed controls and five woody species will be transplanted as seedlings to the plots. Spray irrigation is the treatment aimed to maximize organic contaminant volatilization and water evaporation. Trickle irrigation provides good surface distribution and optimizes use of the most active microbial soil zone (i.e. high organic matter topsoil or litter layer) in leachate renovation while eliminating direct phytotoxic foliar contact with vegetation. Subirrigation is the most aesthetically acceptable application technique in that it eliminates odour emissions and spray drift which can create a "nuisance" to local residents. Distribution through a subsurface tile network also affords the possibility of winter application if placed below maximum frost depth in the soil. This technique, however, does circumvent leachate rejuvenation in the microbially-active topsoil and lower subsoil temperatures may curb microbial activity despite bioactive leachate introduction.

A smaller scale version of the above experimental plot design was installed and operated at the Muskoka Lakes Landfill (District Municipality of Muskoka) in 1987. These data are currently under analysis.

Landfill Recirculation

Two separate sets of cylindrical, bottom draining lysimeters have been established on the University of Guelph campus to enable the testing of two hypotheses:

1. actual evapotranspiration of recirculated MSW leachate can be maximized to high levels on the landfill surface with vegetative cover while not seriously affecting the long-term impervious properties of the clay cap through root ramification.
2. the reported lessening of leachate strength as achieved in the "anaerobic filter" (refuse body) can be greatly enhanced if the leachate is applied to the landfill surface and the vegetated landfill cap.

All lysimeters are approximately 1 m in diameter and 1.2 m deep and all have been filled with a sequence (from top to bottom) of 50 cm of clay soil, 35 cm of MSW leachate-contaminated sand and the balance in geotextile and sand/gravel filter beds.

One assemblage of 15 such lysimeters is being vegetated with various herbaceous grass and legume (e.g. reed canarygrass, trefoil) species to simulate a clay capped landfill whose surface has been stabilized from erosive processes with these vegetation types. Leachate will be applied in accordance with evapotranspirative demand to maintain the clay material at the upper limit of plant-available moisture ("field capacity"). Water and non-volatile contaminant balances conducted from the effluent draining from the lysimeters will permit assessment of the extent of leachate volume and strength reduction, respectively, after recirculation. The relative contribution made by the clay material and the various plant species to the total degree of contaminant attenuation will also be partitioned. A similar experiment will be performed on a second assemblage of 24 lysimeters but these will be planted with various woody species which have a demonstrated resistance to polluted soil conditions.

YIELD OF CORN HYBRIDS GROWN HYDROPONICALLY AND IN SOIL AT ELORA RESEARCH STATION

M.H. Miller, K.G. Alexander and W.A. Mitchell

The highest corn yields previously reported for the Guelph region are much lower than the potential yield. Crop physiologists have estimated that grain yields of 20 t ha^{-1} should be obtainable. These estimates are based on complete light interception between July 15 and September 15, which is achieved with a well-managed crop. The maximum yield recorded for soil-grown plants is 10.7 t ha-1. It has been suggested that soil factors are limiting yields. In a previous study the soil was replaced to a depth of 1 m with a highly fertilized soil:peat:perlite mixture which offered little resistance to root growth. Corn yield on these plots from 1981 to 1984 was identical to that on well- fertilized, irrigated soil plots, indicating that soil structural impedance to root growth was not a yield-limiting factor (Miller et al. 1987; Stypa et al. 1987).

In 1986 and 1987, an experiment was conducted using a hydroponic system to determine the yield obtainable with the above-ground environment. The hydroponic system consisted of 22-L pails of "Turface", a baked clay (International Minerals and Chemical Corp., Blue Mountain, Miss.). Nutrient solution was added automatically at least twice daily. At each watering, sufficient solution (approximately 1 L) was added to cause drainage from the base of the pails. Two plants were grown in each pail and the pails were placed in rows 63 cm apart to give a plant population equivalent to 90,000 plants per hectare.

Growth and yields of several hybrids in the hydroponic system was compared with that of the same hybrids growing in well-fertilized irrigated soil in 1986 and 1987. Final above-ground dry matter and grain yields are reported in Table 1.

Dry matter production in the hydroponic system was greater than that in soil throughout the growing season. Total above-ground dry matter production in soil averaged 82% of that in the hydroponic system in 1986 and 88% in 1987.

Table 1.Total above-ground dry matter and grain yield of corn hybrids grown hydroponically and in soil at Elora Research Station

Hybrid	1986						1987					
	Dry Matter			Grain (15.5% Moist)			Dry Matter			Grain (15.5% moist)		
	Soil	Hydro	Soil/Hydro	Soil	Hydro	Soil/Hydro	Soil	Hydro	Soil/Hydro	Soil	Hydro	Soil/Hydro
	t ha^{-1}					t ha^{-1}			t ha^{-1}			
Pioneer 3925	15.92	19.29	0.83	9.2	10.4	0.88	19.57	22.75	0.86	11.6	14.7	0.79
Pioneer 3945	13.97	17.04	0.82	9.0	10.2	0.88	19.05	21.47	0.89	12.3	14.5	0.85
Pioneer 3949	14.89	18.64	0.80	8.8	11.0	0.80	19.96	21.14	0.94	12.0	13.7	0.88
Asgrow RX308	14.35	17.00	0.84	8.2	9.7	0.85	17.80	21.87	0.81	11.2	13.1	0.85
Co-op 2645	14.39	17.42	0.83	8.8	10.5	0.84	20.52	20.77	0.99	12.7	14.5	0.88
Hyland 2260	14.89	17.94	0.83	8.4	10.4	0.81	18.11	22.75	0.80	11.3	14.4	0.78
PAG SX123	-	-		-	-	-	20.39	22.42	0.91	12.7	15.5	0.82
Mean	14.74	17.89	0.82	8.7	10.4	0.84	19.34	21.88	0.88	12.0	14.3	0.84

Grain yields in the soil were 10 to 20% lower than those in the hydroponic system. The average reduction was 16% in both years. The average yield in the hydroponic system was 10.4 t ha^{-1} (165 bu ac^{-1}) in 1986 and 14.3 t ha-1 (227 bu ac^{-1}) in 1987. The much higher total dry matter and grain yield in 1987 can be attributed to much better growing season weather which resulted in much-above-average corn yields in the region. It is significant that the relationship between the grain yield of soil-grown and hydroponically-grown plants was similar in the two years in spite of the much higher yields in 1987. This indicates that the factor or factors that limit yields on the soil-grown plants is a proportional rather than a fixed limit.

The study shows clearly that the above-ground environment, i.e. climate, is the major factor limiting yields in this region. The adapted hybrids are capable of much greater yields if the climate is more suitable. There remains, however, a soil limitation that restricts grain yield to 80 to 90% of that obtainable with the above-ground environment.

Some possible explanations for the lower yield on soil-grown plants have been investigated.

Analysis of plant samples taken at about the 6-leaf stage and of leaf samples at silking indicate that nutrient concentrations in both soil and hydroponically-grown plants are well within reported sufficiency ranges. Recent studies in this department (see 1986 Annual Report, p. 55), however, have indicated that a P concentration of 5 mg g^{-1} (0.5%) or greater at the 6-leaf stage is required for maximum yield. In 1986 tissue P concentrations in soil-grown plants were at or above this value but in 1987 they were somewhat lower (about 4 mg g^{-1}). Values in the hydroponically-grown plants were above this value in both years. While this may be responsible, at least in part, for the lower yields of soil grown plants in 1987, it is less likely to be the cause of the similarly lower yield in 1986.

Additional studies have indicated that the yield differences cannot be explained by differences in root-temperature regimes. Other studies have led to the conclusion that reduced photosynthesis due to greater water stress in the soil-grown plants would not account for the yield difference.

Two other possibilities are being investigated further.

Although total nutrient concentration in plants will not account for all of the difference, the form of N may be a factor. In the hydroponic system, 40% of the N was in the NH_4^+ form. Although NH_4NO_3 was applied to the soil plots periodically, the NH_4^+-N would be rapidly converted to NO_3^--N so the plants would be dependent primarily on a NO_3^- source of N. An $NH_4^+ + NO_3^-$ supply of N has been shown to result in higher corn yields than a NO_3^- only source (see p. of this report) The timing of the growth difference, however, may negate this possibility. In our experiments comparing N source, the major effect was on grain yield rather than on vegetative growth. The difference between the hydroponically and soil-green plants occurred during vegetative growth as well as in final grain yield.

A second possibility to explain the greater dry matter production and yield on the hydroponic system is related to root exudation. It is well established that a significant portion of fixed CO_2 is released into the rooting medium as non-respiratory carbon. This release appears to be greater in non-sterile than sterile growing medium. It is possible that lower microbial activity in the turface results in less carbon loss from the root system compared to the soil-grown plants.

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CORN HYBRIDS RESPOND DIFFERENTLY TO FERTILITY AND POPULATION

M.H. Miller and W.A. Mitchell

An experiment began at the Elora Research Station in 1985 with the financial support of the Potash and Phosphate Institute, the Foundation for Agronomic Research, and the Ontario Ministry of Agriculture and Food.

The objectives were as follows:

1. To establish the maximum corn yield obtainable with the soil and climate regime at the Elora Research Station.
2. To determine the effect of an initial very high P or K application compared to annual applications.
3. To determine the importance of mid and late season N application in obtaining high yields.

Treatments in 1985 and 1986 included two hybrids (Pioneer 3949 and Asgrow RX308, two populations (65,000 and 90,000 pl ha^{-1}), irrigation vs. no irrigation and six combinations of nutrient application. The fertility variables included combinations of recommended and very high rates of N, P and K.

Details of the treatments and the results in 1985 and 1986 can be found in the 1986 Departmental Annual Report.

In 1987, only one hybrid, Pioneer 3949, was included and all plots were irrigated.

RESULTS

Grain yields in 1987 (Table 1) were more than 30% greater than those in 1985 and 1986 due to a more favourable climate. Higher yields were generally obtained throughout the region in 1987. The highest yields in each year were obtained with Pioneer 3949 at high population density and the highest fertility input. These yields were 9.56 t ha^{-1} (152 bu ac^{-1}) in 1985, 9.31 t ha-1 (148 bu ac^{-1}) in 1986 and 12.18 t ha^{-1} (194 bu ac^{-1}) in 1987.

There was a small (410 kg ha^{-1}) but significant response to irrigation in 1985 but no response in 1986. All plots were irrigated in 1987. There were no significant interactions between irrigation and the fertility/population treatment variables in 1985. Hence the irrigation and no irrigation data have been combined in all further discussions.

There was no response to time of N application (N_2 vs N_3) in either 1985 or 1986. This variable was not included in 1987.

Table 1: Grain yield in 1987.

Fertility	Population (pl ha^{-1}) 65,000	90,000
	(t ha^{-1} @ 15.5% moisture)	
$N_3P_2K_2$	10.88	12.18
$N_1P_2K_2$	10.86	11.21
$N_3P_1K_2$	-	11.20
$N_3P_2K_1$	-	11.30
$N_3P_1K_1$	-	11.40
$N_1P_1K_1$	10.34	-

N_1, P_1, K_1 - Recommended rate

N_3, P_2, K_2 - Very high rate (See 1986 Annual Report for details)

Population x N x Hybrid Interaction

There was no response to N application above the recommended rate (150 kg N/ha) in 1985. There was a significant response to N in 1986, due probably to the high rainfall resulting in either leaching or denitrification. In 1986, the population x N x hybrid interaction was significant. Pioneer 3949 responded to additional N only at the high population density (Table 2). The response of Asgrow Rx308 to N was greater than that of Pioneer 3949 and was the same at both population densities. Also apparent from Table 2 is the fact that Pioneer 3949 responded much more to the increased population than did Asgrow Rx308.

The response to N and population by Pioneer 3949 in 1987 (Table 3) was somewhat greater than in 1985 and 1986 but the population x N interaction was similar.

These results indicate that Pioneer 3949 will respond to increased population if adequate N is supplied.

Table 2: Differential response of two corn hybrids to N rates and population in 1986.

Population	Pioneer 3949			Asgrow Rx308		
	N_1	N_3	Response to N	N_1	N_3	Response to N
(pl ha^{-1})			(kg ha^{-1} at 15.5% moist)			
65,000	8384	8398	14	7841	8484	643
90,000	8748	9214	466	7896	8527	631
Response to Population	364	816		55	43	

Table 3: Response of Pioneer 3949 to N and population in 1987.

Population	N_1	N_3	Response to N
pl ha^{-1}	(kg ha^{-1} @ 15.5% moisture)		
65,000	10,860	10,880	20
90,000	11,210	12,180	970
Response to Population	350	1,300	

P x K Hybrid Interaction

Both hybrids responded to applications of P and K in excess of the recommended rate in both years. However, there was a P x K x hybrid interaction in both years (Table 4). The response of Asgrow Rx308 to both P and K was independent of the level of the other nutrient. However, the response of Pioneer 3949 to P or K was greatest when the other nutrient was also at the higher level.

The P x K interaction also occurred with Pioneer 3949 in 1987 (Table 5). The response to P and/or K, however, was not markedly greater in 1987 than in previous years in spite of the much greater yield potential. This suggests that the P and K fertilizer requirements do not increase as yield levels increase due to more favourable climate. This is consistent with concepts presented years ago by Bray (1954). Because of the low mobility of P and K, these nutrients are absorbed from only a small diameter cylinder of soil around each root (the root surface sorption zone). If the increased yields resulting from a more favourable climate are accompanied by a proportional increase in root growth, a given level of soil P or K will produce the same proportion of the maximum yield as that yield varies due to climate. In 1987, the $N_3P_1K_1$ treatment produced 94% of the $N_3P_2K_2$ treatment yield of 12.18 t ha^{-1}. In 1986 the $N_3P_1K_1$ treatment produced 87% of the $N_3P_2K_2$ treatment yield of 9.31 t h_a^{-1}. Although these data support the % sufficiency concept, it must be recognized that the greater yield will remove more nutrient from the soil so greater maintenance application rates would be required.

The nutrient mobility theory indicates that the N requirements should increase with yield level because N, a mobile nutrient, is absorbed from a large volume of soil (the root system sorption zone). Although the response to N in 1987 was greater than that in 1985 and 1986, the difference is not as great as might be expected. This may be due to a greater release of N from soil organic matter under the more favourable climate in 1987.

Table 4: Differential response of two corn hybrids to P and K averaged over two years.

	Pioneer 3949			Asgrow Rx308		
	P_1	P_2	Response to P	P_1	P_2	Response to P
		(kg ha^{-1} @ 15.5% moist)				
K_1	81333	8550	427	7561	8076	515
K2	8236	9249	1013	7834	8382	548
Response to K	113	699		273	306	

Table 5: Response of Pioneer 3949 to P and K fertilization in 1987.

	P_1	P_2	Response to P
	(kg ha^{-1} at 15.5% moist.)		
K_1	11,396	11,302	(-94)
K_2	11,195	12,183	988
Response to K	(-201)	881	

DISCUSSION

The results of this study indicate that some hybrids, at least, will respond to P and K fertilizer rates in excess of those recommended in Ontario. The increased yields obtained, however, would not pay for the very large amounts of fertilizer applied (500 kg P ha^{-1} and 1050 kg K ha^{-1} over the duration of the experiment) in excess of recommended rates. Because no intermediate rates were included, it is not know whether similar responses could have been obtained with lower rates.

In these studies, the P and K in excess of the recommended rates was broadcast and incorporated into the plow layer. Hence the total volume of the plow layer was fertilized. It is well known that corn has a high requirement for P in relation to plant size during early growth. Barry and Miller (1988) have shown that final grain yield is influenced by the tissue P concentration prior to the 6-leaf stage, regardless of the P supply at later stages.

Although it is generally considered that a band application of P provides an adequate supply of P to the corn seedlings, Barber and co-workers (see Barber and Kovar 1985) have demonstrated that P absorption would be greater if the P was mixed with 10-20% of the soil.

It is possible that the yield responses to the very high P applications in this study could be obtained economically if a lesser amount of P was mixed with a small volume of soil in the planting row.

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SIMULTANEOUS DENITRIFICATION AND FERMENTATION IN WATERLOGGED SOIL

J.W. Paul and E.G. Beauchamp

Accumulation of N_2O (denitrification) was greater in waterlogged soil amended with acetate than in soil amended with glucose during experiments using the acetylene blockage technique. Acetate, a product of fermentation, accumulated in glucose-amended soil before the nitrate disappeared, suggesting the simultaneous occurrence of denitrification and fermentation. Competition for carbon between denitrifying and fermentative bacteria explains the decreased efficiency of glucose as a carbon source for denitrifiers in soil.

The simultaneous occurrence of denitrification and fermentation was also observed in alfalfa- and red clover-amended soil. The simultaneous occurrence of these two processes provides a better understanding of the supply of energy for denitrifying bacteria and the partitioning of nitrate between denitrification and dissimilatory nitrate reduction to ammonium. Fermentative bacteria may provide denitrifying bacteria with fermentation products as readily available energy sources and benefit from the denitrifying bacteria through interspecies hydrogen transfer. Fermentative bacteria are responsible for nitrate reduction to ammonium. Competition for carbon between the denitrifying and fermentative bacterial populations determines the amount of nitrate conserved through dissimilatory nitrate reduction to ammonium. More research is required to further understand the interactions between denitrifying and fermentative bacteria in soil.

NITROGEN CREDITS FOR FORAGE CROPS IN CORN PRODUCTION

R.W. Sheard

The credits to allow for the nitrogen input from a forage crop is an important component of the recommendations for the nitrogen requirement of grain corn. The experiment reported herein is an attempt to assess the nitrogen input of alfalfa and nitrogen fertilized grass in the first, second and third year after plowing.

Four replicates of blocks of bromegrass, fertilized with 300 kg N/ha each year, and blocks of alfalfa were direct seeded and harvested as hay in the two years following the establishment year. One block of corn, which had been in corn since 1967, was grown in each replicate and fertilized with 110 kg N/ha each year. In each test year eight increments of nitrogen, ranging from zero to 200 kg N/ha as ammonium nitrate, were applied to a new set of blocks except for continuous corn where the increments were repeated on the same plots each year.

The yield data were subjected to linear regression analysis to develop a quadratic model for each replicate of a treatment. The maximum economic yield (M.E.Y.) and the nitrogen rate necessary to obtain that yield were computed from the resulting models. The yields and nitrogen rates were then subjected to standard analysis of variance.

In 1985 and in 1987 the models predicted values for the N rates on continuous corn in excess of the limits of 200 kg N/ha imposed by the N rates applied. In these cases the nitrogen rate for M.E.Y. is considered to be the maximum rate of application used in the experiment.

Although there was no difference in M.E.Y. of the corn in the first year following plowing under of the forage species, a previous alfalfa hay crop reduced the nitrogen requirement to zero, whereas nitrogen-fertilized bromegrass reduced the requirement by 50% (Table 1). In the second year continuous corn outyielded corn following alfalfa, however, the corn following alfalfa had only one-third the nitrogen requirement of continuous corn. Nitrogen fertilized bromegrass also appeared to reduce the nitrogen requirement by 22% in the second year following plowing.

In the second year after plowing the corn growing in blocks of each forage species was fertilized with 90 kg N/ha to simulate situations where a nitrogen credit was only allowed for one year following plowing. As a result in the third year following plowing an average reduction in nitrogen requirement of 21% was observed.

The data imply that in the first year after plowing alfalfa will supply all the nitrogen requirement of a seven tonne corn crop whereas nitrogen fertilized bromegrass will provide 50% of the requirement. In the second year alfalfa may still supply 50% of the nitrogen needs of corn whereas nitrogen fertilized bromegrass may be contributing 20%.

In no instance was a superior yield to continuous corn obtained from corn following the forage species. This observation would suggest soil structure was not limiting the yield potential at this site.

***Table 1:** The predicted maximum economic yield (M.E.Y.) of grain corn and the nitrogen requirement in the first, second and third year after alfalfa and after bromegrass.*

Test Year	Crop in Previous Years			Fert N. in Previous Years				M.EY.	N Rate forM.E.Y**	*% Reduc.* in N from Cont.Corn
	1984	1985	1986	1983	1984	1985	1986			
1985	Corn	-	-	110	110	-	-	7160 a*	200††a	-
	Brome	-	-	300	300	-	-	6500 a	102 b	49
	Alfalfa	-	-	0	0	-	-	6700 a	0 c	100
1986	Corn	Corn	-	110	110	Var†	-	6940 a	192 a	-
	Brome	Corn	-	300	300	0	-	6450 ab	149 b	22
	Alfalfa	Corn	-	0	0	0	-	6100 b	64 c	67
1987	Corn	Corn	Corn	110	110	Var	Var	9350 a	200 a	-
	Brome	Corn	Corn	300	300	0	0	9250 a	183 b	8
	Brome	Corn	Corn	300	300	0	90	9270 a	143 c	28
	Alfalfa	Corn	Corn	0	0	0	0	9150 a	169 b	15
	Alfalfa	Corn	Corn	0	0	0	90	9290 a	135 c	32

† Var = Increments of N applied to same plots in 1985, 1986 and 1987.

†† Predicted N rate exceeded maximum application rate use in experiment.

* Values followed by the same letter are not statistically different at P = 0.5

** Calculated using the constraints of corn valued at $95/tonne and nitrogen valued at 56 cents/kg N.

SOIL AND PLANT ANALYSES TRAINING COURSE

D. A. Tel

The International Institute of Tropical Agriculture, I.I.T.A., and the Department of Land Resource Science, University of Guelph conducted the 8th training course for agricultural laboratory technologists working in tropical regions. Six of the courses received financial assistance from the Canadian International Development Agency, C.I.D.A. The Courses were held at the International Institute of Tropical Agriculture (I.I.T.A.) Training Centre in Ibadan, Nigeria.

INTRODUCTION

"There is unanimous agreement that maintaining and actually improving soil fertility through good soil management and the use of organic wastes and mineral fertilizers is essential if the world is to provide the food required by a world population that will almost double by the year 2000. Doubling food production will continue to sap the nutrients from the soil presently under cultivation. Expansion of agriculture to land not now cultivated may require even more fertilizers because of the low nutrient status of much of this land: e.g. the tropics. The increasing need for food and the escalating cost of energy and fertilizers compound the need for improved soil management and efficient use of fertilizers. Soil testing and plant analysis for the guidance of management and fertilizer use can, and will play a major role in increasing in the food supply and the efficiency of its production. Soil testing and plant analysis can thus be looked upon as the ultimate in applied soil and plant science because they are concerned with prediction" (FAO on soil testing: FAO bulletin N 38).

SHORT HISTORY OF THE SOIL AND PLANT ANALYSIS COURSE

Many requests were received by the Analytical Service Lab at I.I.T.A. in 1978 to provide training for laboratory personnel working in the Agronomic sector.

A first 3-week training course was offered in 1980 and had more than 100 applicants from Africa and Asia. After this course many requests were received from participants and institutions to continue to provide this training. Since 1982, courses have been offered annually, with a total of 187 participants representing 39 countries. The number of applications received for each course always far exceed the number of available places. In 1987 and 1988 no scholarships were available through I.I.T.A. resulting in a decline in participants.

GENERAL INFORMATION ON THE COURSE

Most participants are laboratory technologists or agricultural laboratory supervisors (B.Sc. or M.Sc. level or equivalent) and are actively involved in soil and plant analysis at universities, national research institutes, ministries of agriculture and occasionally at private companies or large-scale farms.

The course is made up of lectures, laboratory exercises, seminars, workshops, demonstrations and visits to laboratories. A major part of the time is spent on practical sessions whereby the participants have to work in the laboratory and sometimes in the field. The resource persons for the course come from I.I.T.A., University of Guelph and Universities and research institutes of Nigeria. The course coordinator at I.I.T.A. is Dr. J. Pleysier, Head of the Analytical Service Laboratory.

The course is given in English with simultaneous translation into French. About half of the number of participants usually come from French or Portugese speaking countries.

OBJECTIVES OF THE COURSE

The primary objective of the course is to train laboratory supervisors and senior technologists in the management, methodology, instrumentation and techniques for soil and plant analysis. Special emphasis is given to soils and crops of the tropics.

COURSE TOPICS

The following topics are covered in detail during the 5-week course:

1. Methods and techniques of routine chemical and physical analysis of soil with emphasis on the highly weathered soils of the tropics.
2. Methods of routine plant tissue analysis.
3. Principles and applications of spectrophotometry.
4. Operation and simple maintenance of electrical and electronic instruments.
5. Automated and semi-automated analytical techniques.
6. Statistical considerations and data processing.
7. Methods of sampling, sample preparation and sample storage.
8. Interpretations of data and report writing.
9. Quality assurance and quality control of data.
10. Management of a laboratory in a developing country and problems encountered.
11. Laboratory design and safety.

COURSE MATERIAL PROVIDED TO THE PARTICIPANTS

The following course materials were are used by the students during the course:

1. "Soil and Plant Analysis", eds. D.A. Tel and Myrna Haggarty (study guide).
2. "Selected Methods for Soil and Plant Analysis" ed. by A.S.R. Juo.
3. "Laboratory Exercises for Soil and Plant Analysis". ed. by J. Pleysier.
4. "Automated and Semi-automated Methods for Soil and Plant Analysis" eds. D.A. Tel and P.V. Rao.

Many laboratories in developing countries make use of the above-mentioned manuals and the demand for these publications is great.

ACHIEVEMENTS AND PERFORMANCE OF THE PARTICIPANTS

At the start of the program a benchmark evaluation is done. The participants are examined as to their general knowledge and skills. The benchmark evaluation does show the areas of weakness, and during the course emphasis is placed on those areas. One major weakness observed for many participants was the subject of data calculation.

Sampling and sample preparation

The participants, after having been instructed in how to sample a field, did the actual collecting and preparation of soil and plant samples. Soil and foliar samples were collected by the participants from an I.I.T.A. experimental plot. The following analyses were done:

i) Soil was analyzed for pH, organic carbon, total nitrogen, available phosphorus, exchangeable cations, total acidity, effective cation exchange capacity and particle size. Soil physical tests included moisture retention curve or pF curves, moisture determination by neutron probe or gravimetric method, bulk density, aggregate stability and hydraulic conductivity. These laboratory exercises were supervised by Prof. P. Groenevelt.

ii) Plant tissue was analyzed for total nitrogen, total phosphorus, and macro- and micronutrients, including calcium, magnesium, potassium, sodium, manganese, iron, copper and zinc.

Instruments Used:

The participants were instructed in the proper use and maintenance of the following laboratory instruments:

Balance	Titration equipment
Ovens	Colorimete,
Grinding equipment	Spectrophotomete,
Stirrers	Atomic Absorption Spectrophotometer
Shakers	Flame photometer
pH mete	Auto analyzers
End point Titrator	Black digestors

Seminar, Workshops and Demonstration Sessions

The fourth week covers mainly topics on instrumentation. Various companies involved in the development and sales of laboratory equipment are invited to I.I.T.A. to give seminars on instrumentation for soil and plant analysis. These seminars are also open to the public.

Due to the low volume of sales in Africa the number of companies participating in the seminars has declined in the last couple of years.

Laboratory Reports and Grading

After each laboratory exercise, the participants prepare a report. This report is handed in to the instructor for evaluation and grading. Problems encountered in the analyses and data calculation are discussed with the participant when the graded reports are returned to them. During the last week a final examination is given.

Each participant gives a short presentation on their institution and the problems facing them in managing a laboratory in their country. A lively discussion always follows in which many practical solutions are brought forward. I maintain contact through correspondence with the participants and many solutions have been found through the years based on that discussion period.

Post-Course Cooperation

The participants receive common check samples and are asked to analyze these check samples in their own laboratory, using their own methods, procedures and equipment and then report the analysis results to the Head of I.I.T.A.'s Analytical Service Laboratory. Dr. Pleysier is acting as coordinator for this system of external quality control of analysis data. This inter-laboratory exchange of data will help to achieve measurement compatibility and validity of soil and plant analysis data and to transfer accuracy throughout the routine soil and plant analysis laboratories. These are prerequisites for any scientific communication based on analytical data. Quality control is a very useful service, much needed by the laboratories in the developing countries.

This year concluded the 3 year contract for funding with C.I.D.A. Plans are in the making to offer this course at an advanced level. The need for such training is more acute than ever. Many students in African Universities do not get the opportunity to get "hands on" experience due to lack of operational instruments. A great gap exists in training at the technical level. My hope is that we have done a bit in closing that gap by training 187 people from 39 countries.

INDUSTRIAL WASTE MANAGEMENT THROUGH ENHANCED LAND TREATMENT

R.P. Voroney

The principle investigators in this study are: R.P. Voroney, P.H. Groenevelt, R.G. Kachanoski, L.J. Evans and T.E. Bates. Associated with the project are Dr. V. Rasiah (post-doctoral research associate) and graduate students: Stella Mott, Wen Guang, Sandy Jones and Rhonda Penny. The specific objectives of this research program are: 1) to maximize the biodegradation of organic wastes applied to soil by developing management techniques which optimize the soil physical and chemical properties that affect biological activity, 2) to identify waste-pretreatments which minimize the detrimental chemical and physical properties of the wastes that can affect their biodegradability in soil, and 3) to maximize the degradation rates of recalcitrant organic wastes by enhancement of soil microbial activity. A combination of laboratory, field lysimeter and field plot studies are being used to study the fundamental processes which affect the transport and fate of organic compounds in soil.

The protocol for handling and carrying out research with the real and reference wastes was established for both the laboratory and in the field. A field plot (30 m x 30 m) was established at Polysar Corunna's land treatment site. Four replicated blocks were established based on an initial study site characterization. The main treatment is the effect of tillage: chisel plough (low intensity mixing), rotovated (high intensity mixing) and rotovated with ridge formation (to increase soil aeration and temperature). Each tillage treatment has two-subplots for the oily waste and for the HAGO (reference waste) applications. Equipment to measure soil water and temperature have been constructed and installed at the site. Monitoring will begin in early spring.

An applicator which ensures operator safety has been constructed for precision application of the oily sludge to the plots. Calibration of the applicator will take place this winter. Three storage tanks (2270 litre capacity) have been constructed for uniform mixing of the oily sludge-water suspensions and for efficient transfer of these materials to the plot applicator.

Fifty-four lysimeters have been constructed at a site nearby the University of Guelph, and filled with untreated soil from Polysar Corunna land treatment site. Instruments have been installed for temperature and water content measurements of the soil. Aeration of each lysimeter can be controlled through subsurface pressurized air lines. HAGO was applied to the lysimeters last fall; regular applications will start in spring along with monitoring of biodegradation rates.

Research in laboratory incubation studies indicate that: 1) soil fertility, and 2) soil water content- aeration conditions, have a profound influence on waste biodegradation rates. Our initial experiments were particularly exciting and showed that the chemical form of the N fertilizer was critical for maximizing biological activity. Within the next month we will have substantiated the work. If the latest experiment confirms our initial hypothesis, then industry will want to apply our results to the management of their land treatment operations immediately. Research is presently underway to develop a fertilizer program and to identify other potential management practices which maximize biodegradation rates. Treatments which show promise in the laboratory will be incorporated into the field study this spring.

STOVER DECOMPOSITION AND ORGANIC MATTER TURNOVER IN CONVENTIONAL AND CONSERVATION CORN TILLAGE SYSTEMS

J.P. Winter, D. Ainsworth, and P. Voroney

A decomposition study is being conducted on the long-term continuous tillage plots on a Conestogo silt loam at the Elora research station. Decomposition of crop residues and soil organic matter is accelerated by tillage, but little is known about the dynamics of the decomposition processes involved. The ecology of soil organisms subsisting on corn residues may be substantially different under no-till and conventional till corn. Within these contrasting tillage systems, the objectives of this research are: 1) to compare the decomposition of crop residues by following the fate of ^{14}C and ^{15}N from labelled corn stover, and 2) to characterize the soil faunal population.

The study was initiated in May, 1986, when ^{14}C and ^{15}N dual labelled corn plants were prepared (L.R.S. Annual Report, 1986). A pulse labelling technique for ^{14}C proved sucessful since plants harvested at the end of the growing season were relatively uniformly labelled with the isotope. In the fall of 1986, labelled stover was set out in microplots and the tillage treatments simulated. Using the same techniques, additional corn plants were labelled during the 1987 growing season. This stover was laid out in a transect-microplot across 18 corn rows, half in no-till and half across fall moldboard plow treatments. Soil moisture and temperature are being monitored. Soil samples will be taken from all microplots throughout the 1988 growing season.

Once every two weeks, from May 9 to November 20, soil cores were taken from the surface 5 cm and extracted f for microarthropods. The lowest total numbers were found under conventional tillage corn; no-till corn contained twice the number found for conventional tillage, and grass sod and bromegrass hay contained four times more than conventional tillage. Differences were largely due to changes in the numbers of Prostigmatic and Cryptostigmatic mites, and the collembola Sminthuridae and Isotomidae - Entomobryidae. A more detailed study of the soil biology in the continuous corn treatment will be conducted during 1988.

LAND INVENTORY

NATURAL HERITAGE STEWARDSHIP RESEARCH PROJECT

S.G. Hilts and T.C. Moull

The Natural Heritage League is an umbrella organization of 28 government and non-government groups, all having an interest in the identification, protection and management of important natural heritage areas in the Province. Our research project receives support primarily from League members, as well as some independent private foundations. Current funders include the Ontario Heritage Foundation, World Wildlife Fund, Ministry of Natural Resources, Nature Conservancy of Canada, Wildlife Habitat Canada, Canadian National Sportmen's Shows, the Laidlaw Foundation and the McLean Foundation.

The Natural Heritage Stewardship Research Project is an ongoing research project of the Natural Heritage League, and is developing mechanisms to encourage the conservation and wise management of privately-owned, significant natural heritage areas in Ontario. These mechanisms are referred to as 'stewardship enhancement techniques', and are methods of promoting good land stewardship through the use of a range of agreements and incentives.

Over the course of 1985 and 1986, the Stewardship Project was closely associated with Carolinian Canada, a major land conservation program in southwestern Ontario. Landowner contact, through our project, has been employed to contact approximately 700 private owners of 29 sites, from Toronto and Niagara to areas near Windsor.

Throughout 1987 we continued to be primarily associated with Carolinian Canada, and returned to many of the owners previously contacted to negotiate verbal, non-binding agreements to protect their land from major disturbance. Those recontacted in 1987 had, for the most part, expressed an interest in a Stewardship Award program during the initial contact in 1985 or 1986. The agreement is between the owner and the Natural Heritage League. In return for agreeing to protect his property to the best of his or her ability, the owner receives a Natural Heritage Stewardship Award plaque, signed by the Premier of Ontario and the Chairman of the Ontario Heritage Foundation. The Award program recognizes the contribution that many landowners make in land protection. In many cases, this first-level incentive is all that is required. Two hundred and seventy-seven voluntary stewardship agreements have been negotiated to date, covering some 9,400 acres of natural area. This represents about 40% of the owners that we have discussed the program with, and also 40% of the privately owned natural area with the sites. This aspect of our work will continue on into 1988.

The new Conservation Lands Tax Reduction Program was recently announced by the Ontario government, and was developed in part by this research project. It will offer private landowners a 100% property tax rebate on designated provincially significant natural areas. These areas could include large woodlots, wetlands, or some Niagara Escarpment sites. It is expected to be initiated during 1988, and retroactive for the 1987 calendar year. Participating owners will be required to sign a written agreement to protect the area in question. This will result in a more tangible financial incentive that will be of interest to some owners who can not protect a site through more simple, verbal agreements.

In 1988, stronger agreements and incentives will be investigated, particularly with respect to natural area management agreements and conservation easements. A preliminary workshop on forestry management issues was held here in April, involving interested members of the University community.

Land management agencies associated with the research project since the beginning, particularly the Ministry of Natural Resources Districts and Conservation Authorities, are now beginning to adopt the principles of encouraging the private stewardship of significant sites by providing landowners with an integrated resource management message. Developing voluntary agreements with landowners, through our landowner contact process, has been included in the Ministry of Natural Resources policy to protect provincially significant 'Areas of Natural and Scientific Interest'.

Also important during 1987 has been the development of means through which the program can build upon the rapport established with landowners during the first few contacts. Much of the information and processes developed through our research will be transferred to these agencies over the coming year. Many will also be taking on the responsibility of following up with Stewardship Award recipients through ongoing personal contact, newsletters on natural area protection and management, and by negotiating stronger, cooperative protection agreements with individual landowners.

The Ontario Heritage Foundation has been delegated responsibility for implementing the private stewardship component of the Niagara Escarpment Plan. A pilot project to test our landowner contact process and Stewardship Award program on the Escarpment was developed and approved in 1987, and work will commence on that early in 1988.

Much of our future research will evolve from an external assessment conducted during 1987. The research project was the subject of an extensive evaluation by the Natural Heritage League through its member agencies, principally the Ministries of Natural Resources, and Culture and Communications. The evaluators interviewed representatives from the project, funders, Regional Natural Resources staff and staff from Wildlife Habitat Canada. They also reviewed in detail the project's accomplishments, including the nearly 300 stewardship agreements negotiated covering close to 10,000 acres of natural area. The end result was that overall the project was of high quality and has been extremely successful. As noted earlier, the Ministry of Natural Resources has incorporated the results of the project into its Implementation Strategy for Areas of Natural and Scientific Interest. The Ministry of Culture and Communications, through the Ontario Heritage Foundation, will continue to support our current activities, as well as expanding the focus of the project to other parts of the province, such as the Niagara Escarpment.

We are fortunate to have been able to retain the fulltime services of Jo-Anne Rzadki and Mark Van Patter over the last year to assist with the research project. In October, Jo-Anne was appointed to the Editorial Board of the Natural Areas Association, a U.S. organization for professionals involved with natural area protection and management.

During the summer, we also employed two graduate students, two undergraduates and one high school student to assist with field and computer work. One of the graduates has continued on with a research assistantship, to correlate landowner preferrences for incentive mechanisms, types of agreements and organizations that should deliver programs of this nature.

CLIMATOLOGICAL DATA AT THE ELORA RESEARCH STATION 1987

Month	Daily Mean Temp. (°C)	Corn Heat Units	Degree Days >5C	Degree Days <18C	Total Precipi-tation (mm)	Mean Wind Speed (km/h)	Mean Daily Solar Radiation (MJ/m^2)	Mean Daily Net Radia-tion (MJ/m^2)
January	-6.6			762	50.6	13.1	6.0	-1.3
Dif.	+1.6			-46	-7.7	-5.7	0.0	+0.5
February	-7.3			708	15.0	10.8	11.2	-1.5
Dif.	0.0			-8	-33.9	-6.4	+1.4	-0.5
March	-0.2		17	564	73.2	11.8	15.3	1.0
Dif.	+2.5		+11	-77	-0.9	-6.0	+2.4	-0.6
April	7.9		118	303	44.6	14.0	17.1	6.6
Dif.	+2.8		+54	-83	-25.6	-3.6	-0.1	-0.1
May	13.8	345	271	161	44.6	11.9	21.0	9.1
Dif	+2.4	+122	68	-54	-33.4	-3.2	+0.6	0.7
June	18.5	643	398	42	78.2	10.5**	22.2	10.2
Dif.	+1.4	+63	+35	-19	-8.7	-3.2	+0.5	-1.1
July	20.4	758	476	19	130.4	10.1	22.7	1.3
Dif.	+1.3	+42	+38	-8	+57.4	-1.4	+1.0	-0.1
August	18.0	670	403	43	81.6	11.5	18.4	8.3
Dif.	-0.1	-18	-4	+ 3	+9.5	+1.1	+0.2	-0.5
September	14.3	504*	230	98	71.2	10.3	11.8	4.6
Dif.	0.1	+111	-47	-34	-0.1	-1.4	-2.0	-2.1
October	6.0		49	374	79.4	13.3	8.4	2.0
Dif.	-2.5		-77	+76	+13.1	-0.5	-1.1	-0.9
November	2.4		29	470	74.8	17.2	5.7	0.0
Dif.	+0.5		+4	-10	+9.1	+0.7	+1.0	-0.6
December	-2.0		1	620	70.8	18.6	3.8	-0.9
Dif.	+3.2		-2	-98	-0.7	+1.0	-0.4	-0.1
Year	7.1	2920	1992	4164	814.0	12.8	11.8	4.1
Dif.	+1.1	+320	+74	-356	-21.9	-2.3	+0.3	-0.6

* CHU for Sept. 7 - 11 based on adjusted data from Waterloo-Wellington Airport.

** Based on 24 days of data

"Dif." is the amount that the 1987 value is above (+) or below (-) the 1951-1980 average value.

Publications, Papers presented, Seminars

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R.W. Wein, University of New Brunswick. (now Univ. of Alberta). Land Management Problems in Canada's Largest National Park. (Jan. 27, 1987)

J. Dormaar, Agriculture Canada, Lethbridge. Grazing and Vegetation Influences on Soils in Alberta. (Feb. 2, 1987)

M.H. Miller, University of Guelph. Maximum Corn Yield Research at Guelph. (Feb. 24, 1987)

J.B. Passioura, CSIRO, Australia. Roots as Sensors of Soil Conditions. (March 3, 1987)

L.J. Evans, University of Guelph. Soil Chemistry of Boron and Aluminum. (March 10, 1987)

J. Biggar, University of California, Davis. Establishing and Evaluating Trends in Soil Salinity. (March 13, 1987)

S.A. Abboud, Alberta Research Council, Edmonton. Chemical Forms of Cadmium in Municipal Sewage Sludge-amended Soils. (March 17, 1987)

J. Springer, Ministry of Northern Development and Mines, Sudbury. Vermiculite Resources in Ontario. (March 18, 1987)

B. Shelp, University of Guelph. Case Studies in the Mineral Nutrition of Brasica Crops. (March 24, 1987)

J. Koch, University of Guelph. The Potential Influence of Organic Soils on the Environmental Migration of Iodine from Entombed Nuclear Fuel Waste. (March 31, 1987)

R.H. Shaw, University of California, Davis. Atmospheric Turbulence Studies at the Camp Borden Forest Site. (April 7, 1987)

G.W. Thurtell, University of Guelph. Molecular Diffusion of Gases. (April 15, 1987)

P. Corsini, Sao Paulo State University, Brazil. Research in Soils and Soil Fertility at Sao Paulo. (June 8, 1987)

W. Chesworth, University of Guelph. Rock, Soil and Survival. (October 15, 1987)

R.W. Howitt, Alberta Research Council. Measuring and Modelling Soil Erosion: An Open Landscape Perspective. (October 22, 1987)

J. Hendry, Alberta Agriculture, Lethbridge. Assessment of the Impact of Irrigation in Southern Alberta. (Nov. 19, 1987)

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