CAN-4RC03 *- Optimization of nitrogen fertilization in response to production system uncertainties such as soils, weather and economics across Canada under 4R stewardship*

Collection and restructuring of fertilization experiments databases

Final report

Project duration
July 2014 – March 2015

April 2015

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Summary - Implications of the project to 4R Nutrient Stewardship

Nitrogen (N) fertilization provides essential benefits for food production but its optimal management is subject to a much higher level of complexity than any other nutrient. The fertilizer industry, agronomists, consultants and farmers recognize the 4Rs as the basis for optimum fertilization but their implementation is knowledge-intensive and site-specific. To achieve full implementation of the 4R strategy in the specific context of N applications, the risks and opportunities of N fertilization management with respect to weather, crop response and economics must be addressed at the field scale. Indeed, the acknowledged sources of spatial variability and the uncertainties related to weather and economics are an integral part of the farmer's decision-making process but currently, they are not currently taken into account in the recommendations emanating from experimental science.

Meta-analyses have recently emerged as a necessity in agriculture to review accumulated evidence and extract new meaningful information from knowledge fragments that need to be consolidated. The project will make use of (past and new) datasets from researchers involved in the other activities within this proposal, as well as already available to perform meta-analyses in order to identify crop yield responses and losses to fertilizer N as influenced by soil properties, climatic conditions and 4R management practices. Combination of spatial analysis methods and modelling techniques like multifactorial analysis, state equation representation and fuzzy inference systems will then be used to analyse the relationships between crop response to N fertilization and information on soil properties, crop growth status, meteorological conditions and market status (commodity and N prices).

The outcome of this project is a framework model to manage the sources of uncertainties affecting 4-R practices outcomes on a site-specific basis. It will establish a decision-support system (DSS) will be set up comprising the critical parameters involved in the determination of optimal 4-R practices and the probabilistic processes to compute probability densities of economic and environmental gains and losses. This study needs to be completed if we wish to quantify the consequences of nitrogen management decisions (4R) in interaction with weather and soil properties in a context of uncertainties affecting yield production and risks of N losses. This can only be achieved using innovative probabilistic, time series studies, weather forecasting models, climate change trends, georeferenced data (weather maps, soil maps) and geostatistical procedures planned in the context of this activity.

1. Introduction

Nitrogen (N) fertilization provides one of the most important factors that farmers can manage to influence yield production and farm income. However, N fertilization needs depend on soil properties, weather conditions, management practices and their interactions. Potentially, N use efficiency can be considerably enhanced if these parameters are taken into account and the N fertilization rate is matched to crop demand. Tremblay et al. (2010) proposed an innovative algorithm for N recommendations based on the implementation within a fuzzy inference system of scientific and experimental knowledge on soil features, crop observation and weather conditions effects on N fertilizer needs. More recently, this algorithm was improved thanks to the results of a meta-analysis of 51 studies in North America (Tremblay et al., 2012).

The current initiative is related to complementary investigations on other N fertilization trials databases. More specifically, this project falls within the context of a contribution from Dr. Nicolas Tremblay, research scientist at AAFC, to the CFI – AIP project entitled: “Optimization of nitrogen fertilization in response to production system uncertainties such as soils, weather and economics across Canada under 4R stewardship”. It is based on several N experiments databases (crop yield in response to different rates of nitrogen fertilization) produced by scientists. These databases will be analyzed using the meta-analysis approach, which is suitable for the extraction of knowledge from such big and complex databases. The latter are however formatted differently and characterized by different data and metadata structures. The aim of this project, graciously funded by CFI, is to collect and restructure these databases to prepare them for meta-analysis.

2. Completed work in this project (July 2014 – March 2015)

This project is based on the use of N fertilization data sets to perform statistical analyses on crop yield responses to N fertilizer as influenced by soil properties, climatic conditions and management practices.

Several databases have been collected from Dr. Tremblay or his contacts and processed in the current reporting period. These are indicated in the following list:

- Already available
  - Corn – IRDA (Marc-Olivier Gasser) → collected and restructured
  - Spring wheat – AAFC (Bao-Luo Ma) → collected and restructured
  - Corn – AAFC (Bao-Luo Ma) → collected and restructured
  - Corn – OMAFRA (Greg Stewart) → collected and restructured
  - Corn – Pleine terre (Eric Thibault) → collected and restructured
  - Corn – Rezotage (Aubert Michaud) → collected and restructured

- Corn – Deen (Guelph, Ontario) → collected and restructured
- Corn – Fredericton (Bernie Ziebarth) → collected and restructured
- Potato – Fredericton (Bernie Ziebarth) → collected and partially restructured
- Corn – COOP → collected and restructured
- Corn – Laval University (Léon-Étienne Parent) → collected and restructured
- Corn – Harlaka (Noura Ziadi) → collected and restructured
- Corn – Promarc (Noura Ziadi) → collected and restructured
- Corn – CFI-AIP (Claudia Wagner-Riddle) → collected and restructured
- Corn – CEROM (Gilles Tremblay) → collected and restructured
- Barley – Alberta (Dick Puurveen) → collected and restructured

Other databases will possibly be processed in the next year of the project, among them:

- Committed
  - Potato – Laval University (Léon-Étienne Parent)
  - CFI-AIP – (Miles Dyck)
  - Potato – CFI-AIP (Mario Tenuta) → partially collected and partially restructured
  - Cereal – CFI-AIP (Jeff Schoenau) → partiallycollected and partially restructured
- Potential
  - Spring wheat – Alberta (Rigas Karamanos)
  - Canola – Alberta (Rigas Karamanos)
  - CFI-AIP – (David Burton)
  - CFI-AIP – (Craig Drury)
  - CFI-AIP – (Linda Hall)
  - CFI-AIP – (Alison Eagle)
  - Alberta (Alicia Schoepp)
  - Alberta (Lei Sun)
  - Alberta (Len Kryzanowski)
  - Alberta (Rory Degenhardt)

Weather data are available from experimental farms or from Environment Canada weather stations. The structuring of the DB was performed using Matlab programming.

For each original database, a first output (called Output1) was produced in the form of a restructured DB. The format of Output1 is common to all DBs and contains complete raw information on data (yield for several N rates) and meta-data (dates, location, soil, weather, management practices, cultivar, etc.). Generally, weather metadata (daily Tmin, Tmax, rainfall) are stored in a separate sheet of the same Excel file. Another restructured DB (called Output2) is produced from Output1 by keeping only the processed data that are used for meta-analysis. Tables 1 and 2 give a summary of DBs (Excel files) that were processed, including main “yield–N rates” data and weather files.

Table 1. Collected and processed databases

DB author	Excel file	Crop	Received files		Processed data		
			Data	Weather	Output1	Weather	Output2
M-O. Gasser	Sites 2007-2009	Corn					
É. Thibaut	Meta-fichier	Corn					
	Meta-fichier_ET	Corn					
M. Bushong	2008_LCB_NR	Corn					
	2008_LCB_REG	Corn					
	2009_HAS_NR	Corn					
	2009_LCB_NR	Corn					
	2009_LCB_REG	Corn					
	2010_HAS_NR	Corn					
	2010_LCB_NR	Corn					
	2010_LCB_REG	Corn					
	2012_LCB_REG	Corn					
	2013_EFAW_IC	Corn					
	2013_LCB_IC	Corn					
A. Michaud	REZOTAGE 2012_2013	Corn					
BD Ontario	BD Ontario	Corn					
B.-L. Ma	NSW00PEI	Wheat					
	N-SW00CEFyld	Wheat					
	N-Sw00Quebec	Wheat					
	NSW00YLDGBF	Wheat					
	NSWYLD99GBF	Wheat					
	swn99yldcef	Wheat					
	N-SW99QcYLD	Wheat					
	NSw99PEI	Wheat					
	NSW98YLDCEF	Wheat					
	N-rep_00-02	Corn					
	N-rep_05-07	Corn					
B. Zebarth	CM	Barley Potato					
	GHGB&CNT	Barley					
	HLB	Barley					
	CRN	Corn					
	GHGC	Corn					
	ACD	Potato					
	Agrium	Potato					
	CR	Potato					
	DST	Potato					
	GAPS	Potato					
	GE	Potato					
	GHG	Potato					
	HLR&HLS	Potato					
	PQ	Potato					
	RG	Potato					

DB author	Excel file	Crop	Received files		Processed data		
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M-O. Gasser	Sites 2007-2009	Corn					
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M. Bushong	2008_LCB_NR	Corn					
	2008_LCB_REG	Corn					
	2009_HAS_NR	Corn					
	2009_LCB_NR	Corn					
	SPLT	Potato					
	HLW	Wheat					
	HLWT	Wheat					
N. Ziadi	Harlaka	Corn					
	Promarc	Corn					
L.-É. . Parent	Ulaval1	Corn					
	Ulaval2	Corn					
	Ulaval3	Corn					
	Ulaval4	Corn					
	Ulaval5	Corn					
G. Tremblay	CEROM_97-08	Corn					
	CEROM_09-14	Corn					
	CEROM_2010	Corn					
Coop	Coop	Corn					
B. Deen	IPNI2009-14	Corn					
C.Wagner-Riddle	CFI-AIP	Corn					
J. Schoenau	Jeff	Cereal					
D. Puurveen	IPNI2010-13	Barley					
M. Tenuta	Xiaopeng, G.	Potato					

Raw DBs provided by N. Tremblay

Raw DBs partially provided by N. T.

DBs processed by M. Aubrun

DBs partially processed by M. A.

Table 2. Number of sites treated

DB author	Crop	Output1	Output2
É. Thibaut	Corn	39	36
A. Michaud	Corn	58	58
BD Ontario	Corn	94	80
B.-L. Ma	Corn	9	9
B. Zebarth	Corn	17	17
N. Ziadi	Corn	18	6
L.-É.. Parent	Corn	179	83
G. Tremblay	Corn	183	183
B. Deen	Corn	12	6
C. Wagner-Riddle	Corn	8	4
B.-L. Ma	Wheat	108	
D. Puurveen	Barley	4	
Total		729	482

As recommended by Dr. N. Tremblay, the format of Output1 DB was defined as follows:

- LAT : latitude of the field
- LONG : longitude of the field
- TOWN : name of location (municipality, town, village)
- SITE : site name
- FIELD : field name or number
- YEAR : year of the collected data
- CROP : crop type
- PREV : previous crop
- CULTIVAR : name of cultivar
- CHU_CV: corn heat units of the cultivar
- SEED_RATE : seeding rate per hectare
- TILLAGE : tillage (conventional or conservation)
- SOW_DATE : sowing date
- SPLIT_DATE : split application date
- No_DAY: number of days between sowing and split application
- HARVEST_DATE : harvest date
- ATXR : soil surface textural class (horizon A)
- ASAND : percentage of sand in the soil surface (horizon A) (%)
- ASILT : percentage of silt in the soil surface (horizon A) (%)
- ACLAY : percentage of clay in the soil surface (horizon A) (%)
- SOM : soil surface organic matter (%)

- PH : soil surface pH (pH H_2O or pH KCL)
- XX_NXXX_depth : soil nitrate (NXXX=NO3N) or ammonium (NXXX=NH4N) at sowing (XX=SOW), split (XX=SPLIT) or harvest (XX=HARVEST) for depth of 0-15 cm, 0-20 cm, 0-30 cm, etc (depth=015, 020, 030) (kg N/ha)
- SOIL_X_depth : phosphorus (X=P) or potassium (X=K), etc in soil for depth of 0-15 cm, 0-30 cm (kgX/ha)
- NSOW : Nitrogen fertilizer rate applied at sowing (kg N/ha)
- NSOW_SOURCE : Nitrogen fertilizer source at sowing
- NSOW_APP: Nitrogen fertilizer application method at sowing
- NSPLIT : Nitrogen fertilizer rates applied at split application (kg N/ha)
- NSPLIT_SOURCE : Nitrogen fertilizer source at split application
- NSPLIT_APP: Nitrogen fertilizer application method at split application
- NTOT : total Nitrogen fertilizer rate (NSOW+NSPLIT) (kg N/ha)
- MANURE : manure history
- P : Phosphorus fertilizer rate applied (kg P_2O_5/ha)
- K : Potassium fertilizer rate applied (kg K_2O/ha)
- NOPT : optimal Nitrogen (kg N/ha)
- NoREP : number of replications
- GRAIN_MOIST : grain moisture (%)
- YIELD : grain yield (t/ha)

The weather sheet contains the following columns:

- The Julian day of the year
- The maximum daily temperature in °C
- The minimum daily temperature in °C
- Daily precipitations in mm
- Daily irrigation in mm, if applicable

The Output2 DB is designed to be simple to use for meta-analysis processing. It contains the following fields:

- IDENTIFICATION : concatenation of the fields 'TOWN'_'SITE'_'FIELD'_'YEAR'
- CROP : crop type
- PREV : previous crop
- TILLAGE : tillage (conventional or conservation)
- ATXR : soil surface textural class (horizon A)
- ASAND : percentage of sand in the soil surface (horizon A) (%)
- ASILT : percentage of silt in the soil surface (horizon A) (%)
- ACLAY : percentage of clay in the soil surface (horizon A) (%)
- SOM : soil surface organic matter (%)

- CHU_m30p15 : Corn Heat Units calculated from 30 days before split application to 15 days after (46 days)
- PPT_m15p15 : cumulative precipitation (daily rain mm) calculated from 15 days before split application to 15 days after (31 days)
- SDI_m15p15 : Shannon diversity Index calculated from 15 days before split application to 15 days after (31 days)
- AWDR_m15p15 : abundant and well-distributed rainfall (PPT * SDI)
- NSOW_CONTROL : Nitrogen fertilizer rate applied as control at sowing (kg N/ha)
- NSPLIT_CONTROL : Nitrogen fertilizer rate applied as control at split (kg N/ha)
- NSOW : Nitrogen fertilizer rate applied at sowing (kg N/ha)
- NSPLIT : Nitrogen fertilizer rate applied at split (kg N/ha)
- Y : a variable called « effect size » used for meta-analysis. Y is the average over replications of log(RR), where RR is the response ratio defined by: RR=Yield/Yieldcontrol
- VY : is the pooled variance of Y over the replications
- DF : degrees of freedom of Y (DF = NoREP – 1)

3. Modifications/Difficulties

There were difficulties or challenges during the January-March 2015 period, mainly related to experimental design or to lack of information in some databases.

- The first difficulty was to define a control treatment. It was defined according to the two following criteria:
  - Less than 75 kg N/ha at sowing
  - 0 kg N/ha at split application
- The second difficulty was to define the minimum number of day between the sowing and the split application date to calculate the weather parameters of the “Output2” databases. This condition was established at 16 days.
- The third difficulty was to calculate the weather parameters of the “Output2” databases when the date of the split application is unknown. It was decided to use three different dates (June, 15th, 20th and 25th) to be tested in meta-analysis.
- The “Corn – Laval University (Léon-Étienne Parent)” database contains only means and MCE (standard deviation^2) values of yield by treatment and by site. For each site, we took the same standard deviation (the square-root of the MCE) for all the treatments.
- The last difficulty concern sites that contain two Nitrogen fertilizer rates identical but the fertilizer sources or application methods are different. In the “Output2”, the two Nitrogen fertilizer rates were considered separately.

4. Schedule and Budget

With reference to the project work plan, the work completed in the all period is mainly related to:

- Work package 1: for the collection of (complete or partial) databases from 16 researchers;
- Work package 2: for the restructuring completely of 729 sites for the output1 and 482 sites for the output2;
- Work package 3: for three technical reports.

Table 3 gives, according to the project schedule, an assessment of the percentages of the work performed for each activity of the project's three work packages. The progress of the project complies with the original schedule.

All the project cost was entirely used for human resources.

Table 3. Project schedule and progress

Schedule	2014						2015		
Activities	1	2	3	4	5	6	7	8	9
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Work package 1: Obtain and secure databases									
Activity 1.1: Collection of existing databases	70%								
Activity 1.2: Collection of promised databases	10%	40%	70%	80%	90%				
Activity 1.3: Analysis of data and metadata structures of original DB		15%	30%	40%	50%	100%			
Activity 1.4: Complete databases when necessary			20%	40%	50%	70%	100%		
Work package 2: Structuring and restructuring of databases									
Activity 2.1: Determination of a structure and format for the output DB	50%	100%							
Activity 2.2: Assemblage of data sets		10%	20%	40%	60%	70%	80%	100%	
Activity 2.3: Quality control of output databases				20%	30%	50%	70%	80%	100%
Work package 3: Production of reports and deliverables and meetings									
Activity 3.1: Monthly progress reports		12%	25%	30%	40%	50%	70%	80%	100%
Activity 3.2: Quarterly technical reports, final report and deliverables			30%			50%			100%
Activity 3.3: Quarterly and final meetings			30%			60%			100%

Milestones for technical reports and meetings

5. Deliverables

- Output1 and Output2 of "Eric Thibault"; (In two parts)
- Output1 and Output2 of "Aubert Michaud";
- Output1 and Output2 of "Noura Ziadi - promarc";
- Output1 and Output2 of "Noura Ziadi - harlaka";

- Output1 and Output2 of “Bernie Zebarth - CRN”; (In three parts)
- Output1 and Output2 of “Bernie Zebarth - GHGC”;
- Output1 and Output2 of “BD Ontario”;
- Output1 and Output2 of “Baoluo - Corn 2000-02”
- Output1 and Output2 of “Baoluo - Corn 2005-07”
- Output1 and Output2 of “Leon-Etienne Parent – Corn” (In five parts)
- Output1 and Output2 of “Gilles Tremblay – 1997-2008”
- Output1 and Output2 of “Gilles Tremblay – 2009-2014” (In two parts)
- Output1 and Output2 of “Coop”
- Output1 and Output2 of “Bill Deen” (In six parts)
- Output1 and Output2 of “Claudia Wagner-Riddle”
- Output1 of “Baoluo – Wheat” (In eleven parts)
- Output1 of “D. Puurveen – Barley” (In four parts)
- Report 1 and Report 2;
- The current report.