IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

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Crop Nutrient Response Tool

4R nutrient stewardship

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Agrium Inc.

Arab Potash Company

Belarusian Potash Company

CF Industries Holdings, Inc.

Compass Minerals Specialty Fertilizers

Incitec Pivot

International Raw Materials LTD.

Intrepid Potash, Inc.

K+S KALI GmbH

The Mosaic Company

OCP S.A.

PotashCorp

Qatar Fertiliser Company (QAFCO)

Simplot

Sinofert Holdings Limited

SQM

Toros Tarım

Uralkali

Formed in 2007 from the Potash & Phosphate Institute, the **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.

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Outline

1. Why use a Crop Nutrient Response Tool?
2. How it works
3. How to use it
4. Versions
5. Outputs: MERN and NUE
6. Practicum: Analyzing your data

- *Slides: http://nane.ipni.net*
- *CNRT: http://nane.ipni.net/article/NANE-3068*

4R nutrient stewardship

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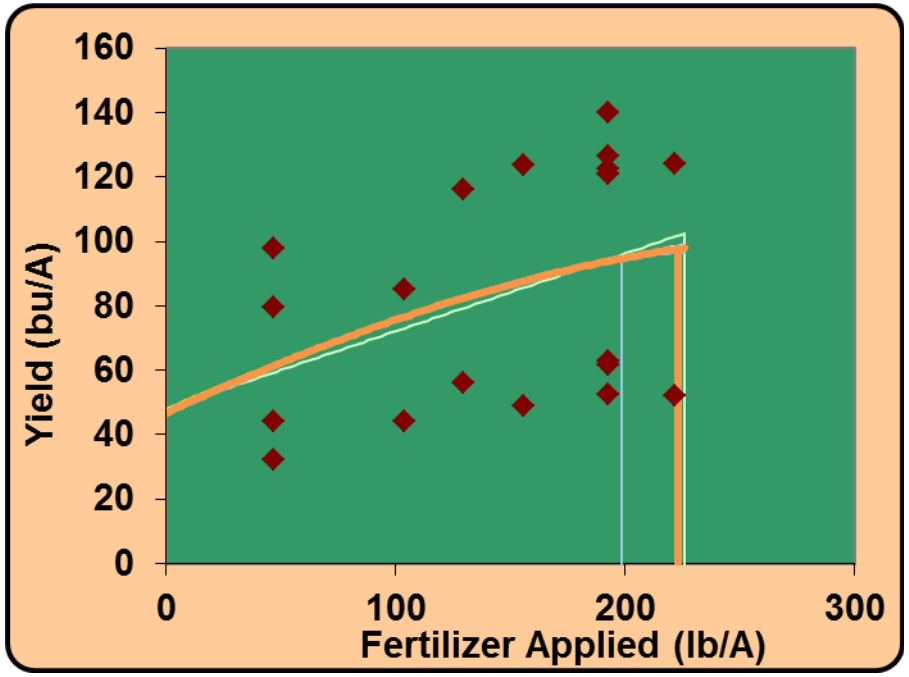
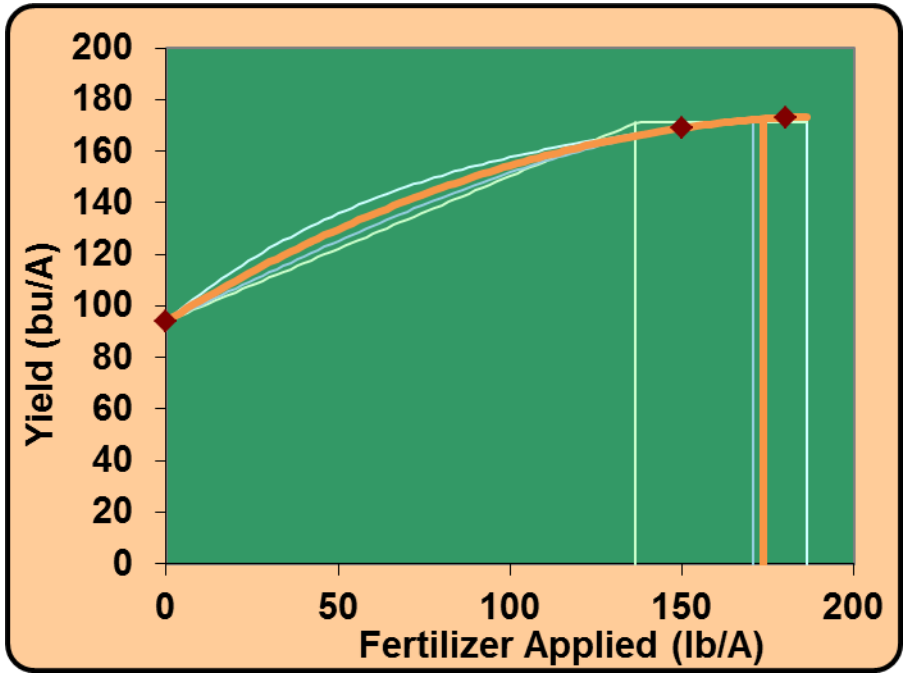
Why use a Crop Nutrient Response Tool?

- To assist interpretation of on-farm rate response trials





- Supports adaptive management for 4R Nutrient Stewardship

4R nutrient stewardship

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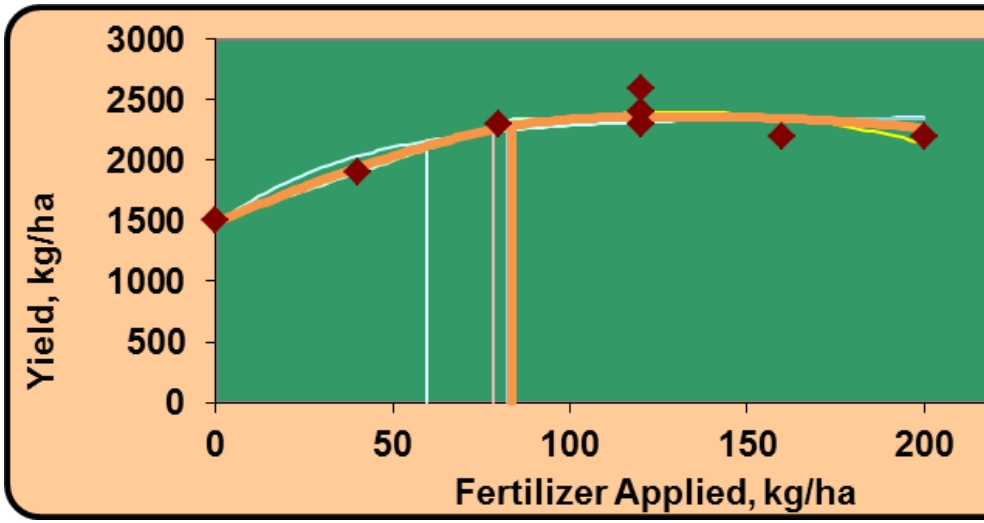
Why use a Crop Nutrient Response Tool?

- To quickly re-analyze published literature
  - Check for artifacts arising from selection of mathematical model
  - A more useful analysis than multiple comparisons procedures

Table 2. Effects of soil texture and N fertilization on wheat

Source of variation	Yield straw	Yield grain†	Total yield
	——————-Mg ha^{-1}——————		
Soil textural group			
C§	3.2b¶	2.1a	5.4b
L	4.4a	2.6a	7.1a
Sg	2.6c	1.9a	4.5c
Sp	2.9c	2.1a	4.9bc
N fertilization			
N0	2.0d	1.5d	3.5d
N40	2.7c	1.9c	4.7c
N80	3.2b	2.3b	5.5b
N120	3.6a	2.3b	5.9a
N120t	3.6a	2.6a	6.3a
N120s	3.5a	2.4ab	5.9a
N160	3.7a	2.2b	5.9a
N200	3.8a	2.2b	6.0a



Why use a Crop Nutrient Response Tool?

- Best estimate of most economic rate of nutrient (MERN) = economically optimum nutrient rate (EONR)
- Estimation of nutrient use efficiencies (NUE), calculated at the optimum rate:
  - PFP (partial factor productivity) = $Y/MERN$
  - AE (agronomic efficiency) = $(Y-Y_0)/MERN$
  - PNB (partial nutrient balance) = $U_H/MERN$
  - RE (recovery efficiency) = $(U-U_0)/MERN$

Why these 5 curves?

- Quadratic
  - Fits a yield decline at high rates
  - Tends to overestimate MERN where there is a plateau
- Quadratic-plateau
  - Widely accepted general curve
- Mitscherlich
  - Fits the concept of a maximum potential yield
- Linear-plateau
  - If the data from many rates fit its pattern, no other curve gives the same EONR
- Spherical-plateau
  - Similar to QP, but coefficients more meaningful
  - A = Y_0, B = ΔY, C = AONR

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How it works

- Each equation is represented in worksheet C
- Starts with default initial values for coefficients A, B and C
- Sum of squared deviations minimized using Solver, manipulating A, B and C
- Gives higher-precision results than using Excel's chart trendline function

Quadratic (Q):	$Y = A + BX + CXX$
Quadratic Plateau (QP):	$Y = A + BX + CXX$ when $X<B/-2C$; otherwise $Y=A + BB/-2C + BB/4C$
Mitscherlich (M):	$Y = A + Bexp(CX)$
Linear-Plateau (LP):	$Y = A + BX$ when $X < (C - A)/B$; otherwise $Y = C$
Spherical-plateau (S):	$Y = A + B(3X/(2C) - 0.5(X/C)^3)$ where $X < C$; otherwise $Y = A + B$

How to use it

- Enter rate and yield data
  - Type, or cut and paste
  - Clear existing data first
- Enter crop and fertilizer prices
- Enter crop nutrient content and N harvest index
  - Used in NUE calculations, and to set constraints on parameters
- Click “Fit”
- Visually inspect response curves
- Enter site details, if desired
- Record data by “Append site information to summary”

User Inputs

ESSENTIAL INFORMATION	
Crop ($/bu)	6.00
Fertilizer ($/lb)	0.60
Price ratio (f/c)	0.100
Crop nutrient content (lb/bu)	0.65
Nutrient harvest index	0.666

Enter crop price received per unit of yield. Deduct any per-unit-of-yield charges for expenses such as crop drying, haulage, etc.

Enter price paid per unit of fertilizer nutrient.

Price ratio = fertilizer nutrient price divided by crop price. Units of bushels of crop required to purchase one pound of fertilizer nutrient.

Assumes harvest index for the nutrient does not change across the rates applied. Default value for corn is 0.67

Assumes grain N content is constant for all rates applied. Default value for corn is 0.65

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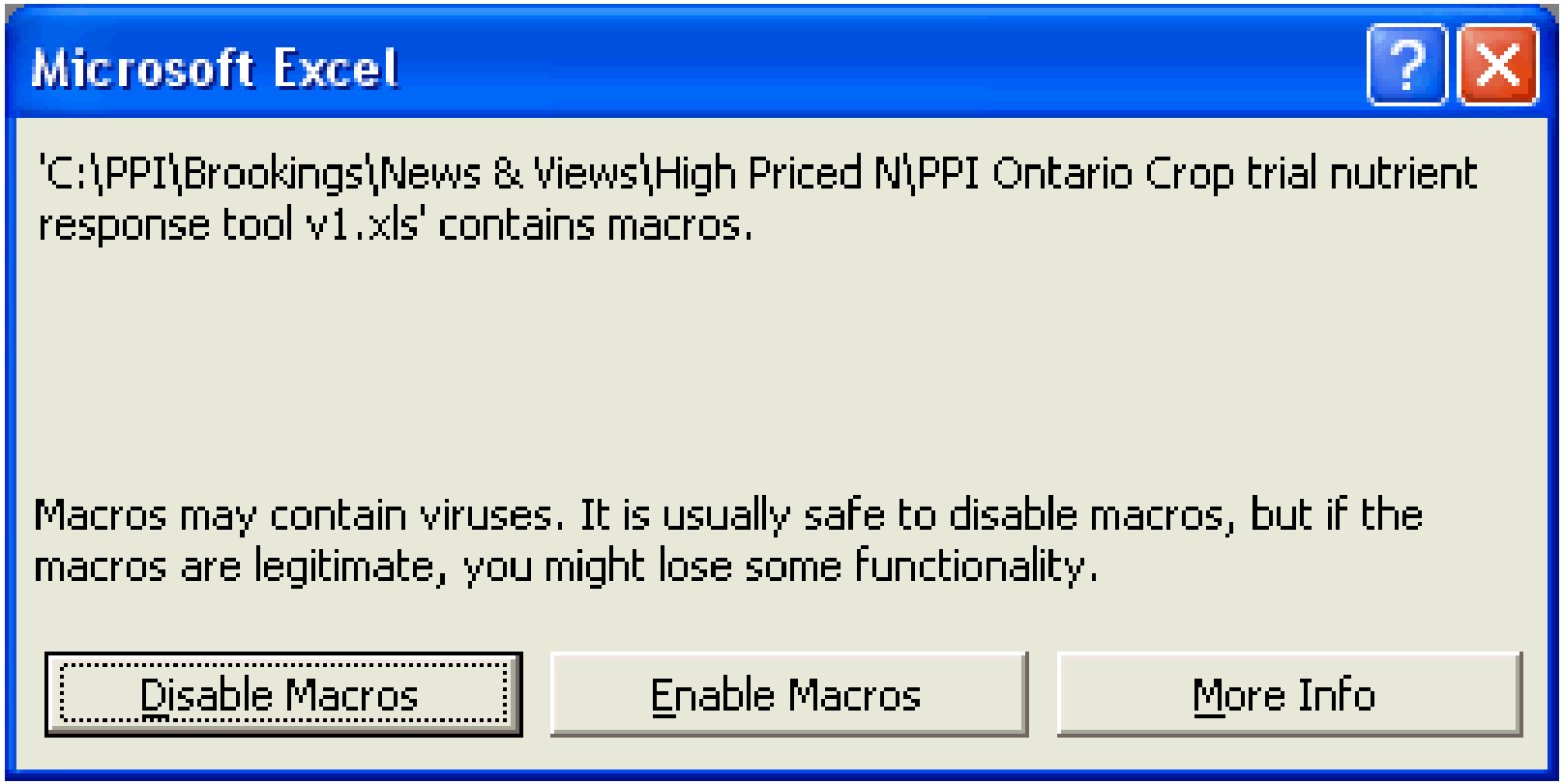
User Inputs

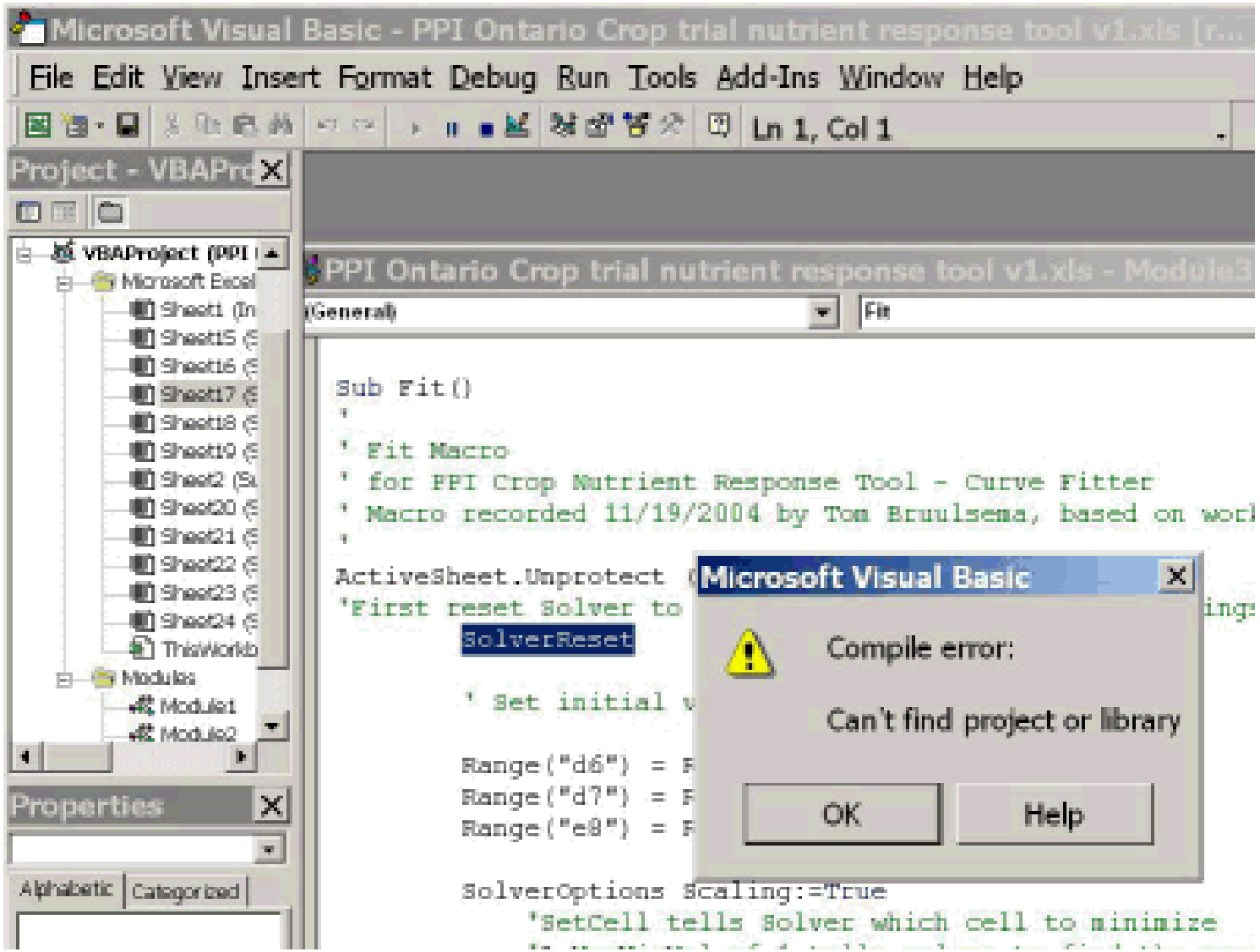
Fertilizer rate, lb/A	Crop Yield, bu/A
0	94
150	169
180	173

- Enter 3 to 40 rate-yield data pairs
- Type or paste
- Order does not matter

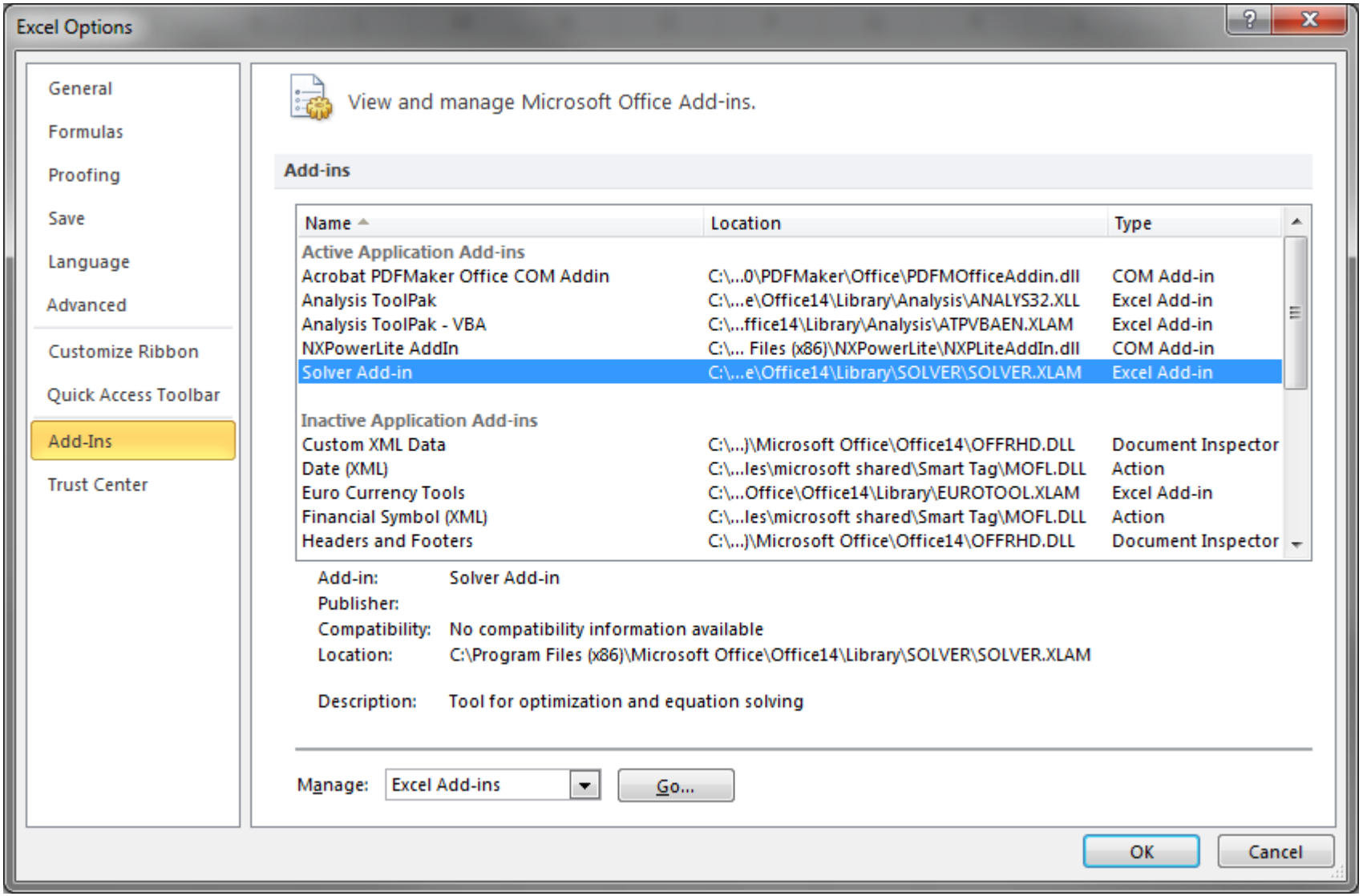
Enable macros



Error – Solver missing

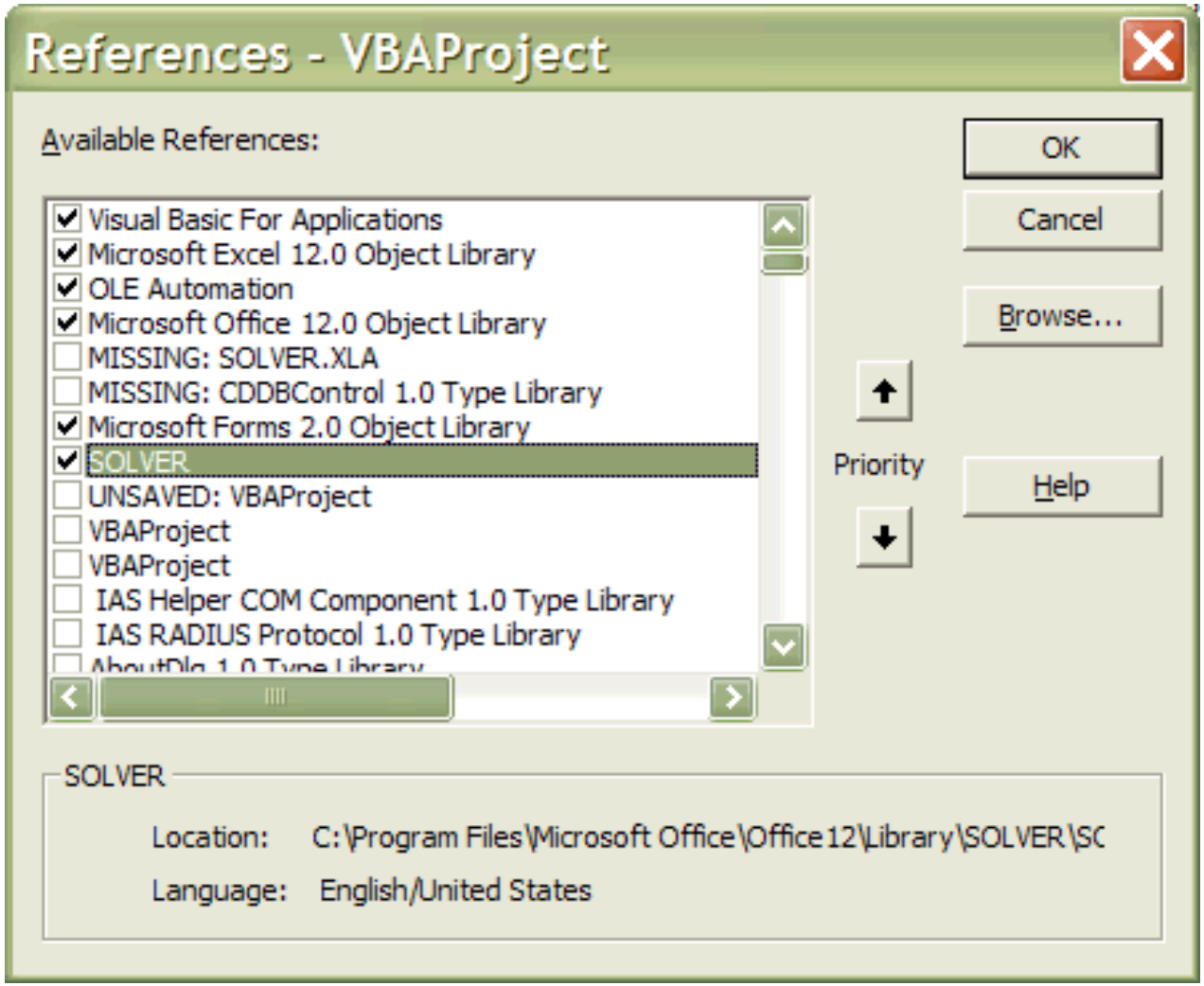


Solver Add-in



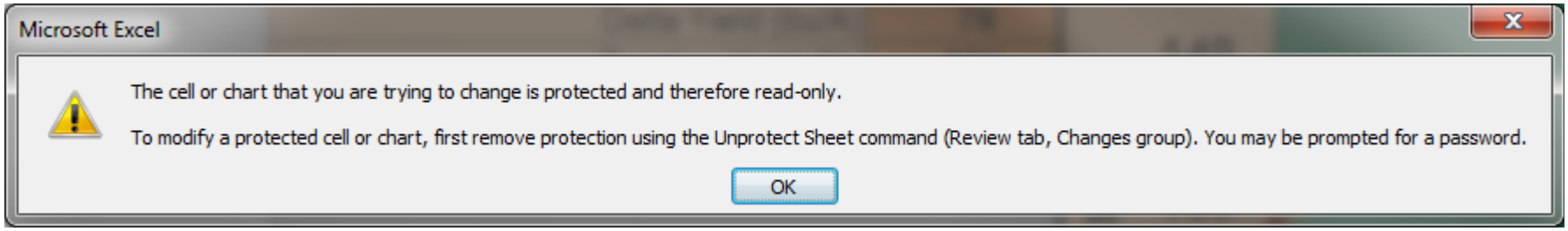
Solver Add-in

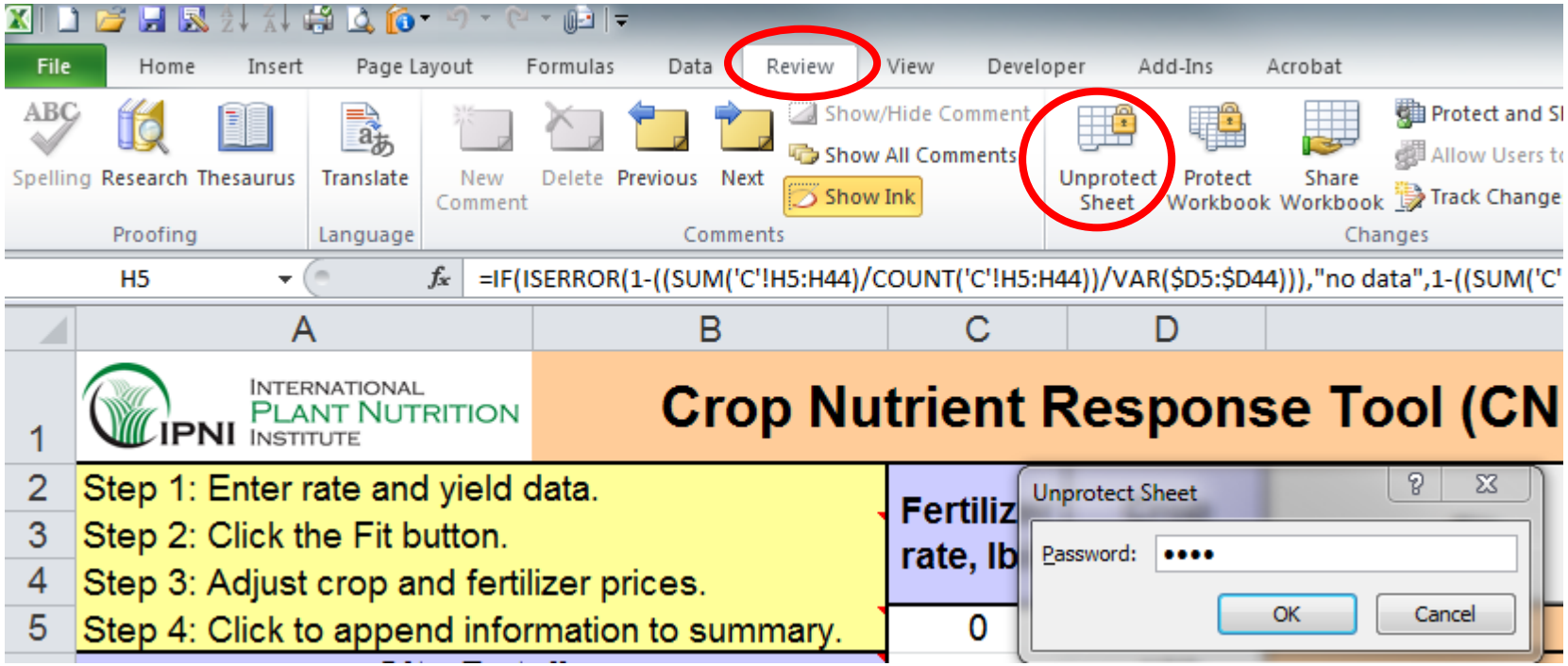
- May also need to add Solver to the list of references



Protection

- “protect sheet” feature is used – password is “ipni”





Versions

- US units
- Metric
- Comparison mode

Outputs: MERN

- MERN = EONR
  - Most economic rate of nutrient = economically optimum nutrient rate
  - The rate at which the last increment of nutrient has paid for itself in crop yield response
  - Each equation has an analytical solution
  - The mean yield response does not… MERN determined from lookup function on the R^2-weighted average response curve (MERN of the mean yields, not the mean of the MERNs)

Quadratic (Q):	MERN = (R-B)/(2C)
Quadratic Plateau (QP):	MERN = (R-B)/(2C)
Mitscherlich (M):	MERN = (1/C)*ln(R/(B*C))
Linear-Plateau (LP):	MERN = (C-A)/B if B>R; else MERN = 0
Spherical-plateau (S):	MERN = SQRT(C^2 - 2*BR*C^3/(3*B))

Outputs: MERN

- MERN = EONR
  - estimated from price ratio and slope of response curve. When the curve appears to suggest that MERN is beyond the range of rates applied, MERN is limited to no more than 10% higher than the highest rate applied.
  - Also gives the yield at MERN

MERN (lb/A):
Yield @ MERN (bu/A)

Outputs: NUE @ MERN

- PFP - Yield divided by nutrient applied, bu/lb.
- AE - Yield increase per unit of nutrient applied, bu/lb.
- PNB - Estimated nutrient use efficiency calculated as ratio of nutrient removed in the grain to nutrient applied at most economic rate. “Estimated," because N content in grain is assumed the same at all rates. Includes applied manure N entered in cell B24.
- RE - Estimated nutrient use efficiency estimated as increase in nutrient uptake into the aboveground portion of the plant as a proportion of the nutrient applied. Depends on data provided in cell B25 for crop nutrient content, and in cell B26 for nutrient harvest index. "Estimated," because N content of grain, and N uptake, are assumed equal for all rates.

Partial Factor Productivity (PFP), bu/lb
Agronomic Efficiency (AE), bu/lb
Estimated Partial N Balance (PNB), %
Estimated Recovery Efficiency (RE), %

Nutrient Use Efficiency (NUE

NUE Term	Calculation	Typical values for cereal
PFP – Partial factor productivity of applied nutrient	Y/F	40 to 80 units of cereal grain per unit of N
AE – Agronomic efficiency of applied nutrient	$(Y-Y_0)/F$	10 to 30 units of cereal grain per unit of N
PNB – Partial nutrient balance (removal to use ratio)	U_H/F	0 to greater than 1.0 <1 surplus >1 mining
RE – Apparent crop recovery efficiency of applied nutrient	$(U-U_0)/F$	0.3-0.8 – cereal N 0.1-0.3 – first year P 0.5-0.9 – long term P

Outputs

- Simple indicators of “responsiveness”
- Calculated at MERN

Delta Yield (bu/A)
Relative Yield (%)

Practicum: Analyzing your data

Technical stuff on worksheet C

Technical

Constraints:

	Maximum					Minimum					Fitting
	Q	QP	M	LP	S	Q	QP	M	LP	S	Tolerance
A	135	135	275	135	135	45	45	92	45	45	50%
B	1.54	1.54	-0	1.28	138	0	0	-138	0	0	50%
C	-1.0E-07	-1.0E-07	-1.0E-07	183	1,255	-1	-1	-0.019304	92	0	30%

Data for Graph:

Most Economic Rate					Yield at Most Economic Rate					Mean	Mean
Q	QP	M	LP	S	Q	QP	M	LP	S	MERN	Y@mern
160	150	187	114	135	0	0	0	0	0	154	0
160	150	187	114	135	182	180	182	180	179	154	179

Nutrient content (lb/bu): 0.65000
NHI: 0.66600

These two cells, carried from page A, set constraints on initial slope assuming maximum efficiency (REN) is 100% + fitting tolerance.

Initialization

	Mean				
	Q	QP	M	LP	S
A	90	90	183	90	90
B	1	1	-69	1	69
C	-0.05	-0.05	-0.01	137	200.00

Maximum rate for curves
200

1255 sum of yields and rates entered (to detect n
1255 set by the FIT macro when finished
TRUE detects whether the FIT macro has been run

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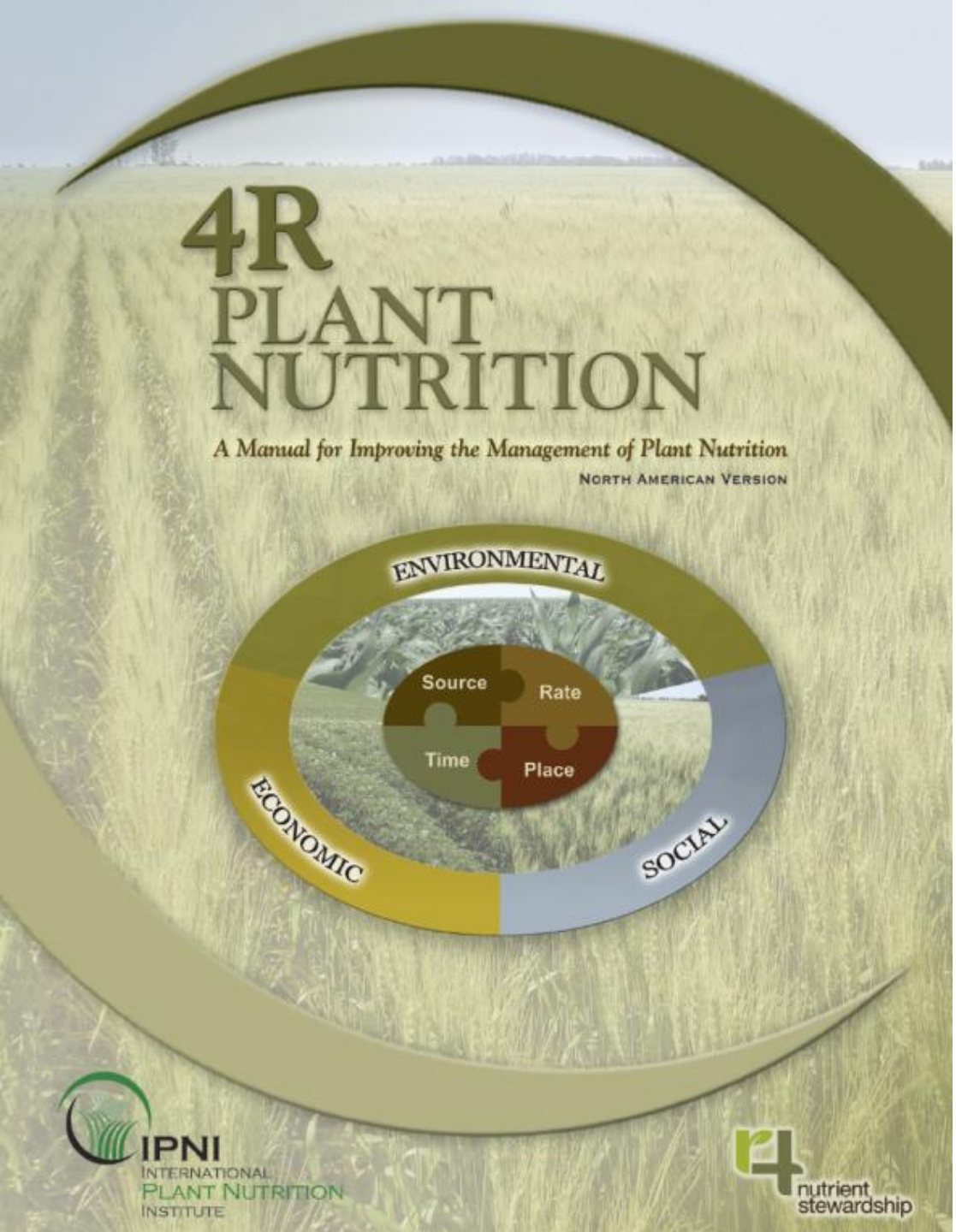
Summary

- The Crop Nutrient Response Tool can
  - Summarize rate response data from field trials
  - Help visualize the data
  - Enable comparisons of profitability and nutrient use efficiency
  - Support adaptive management in 4R Nutrient Stewardship



Comments Welcome

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