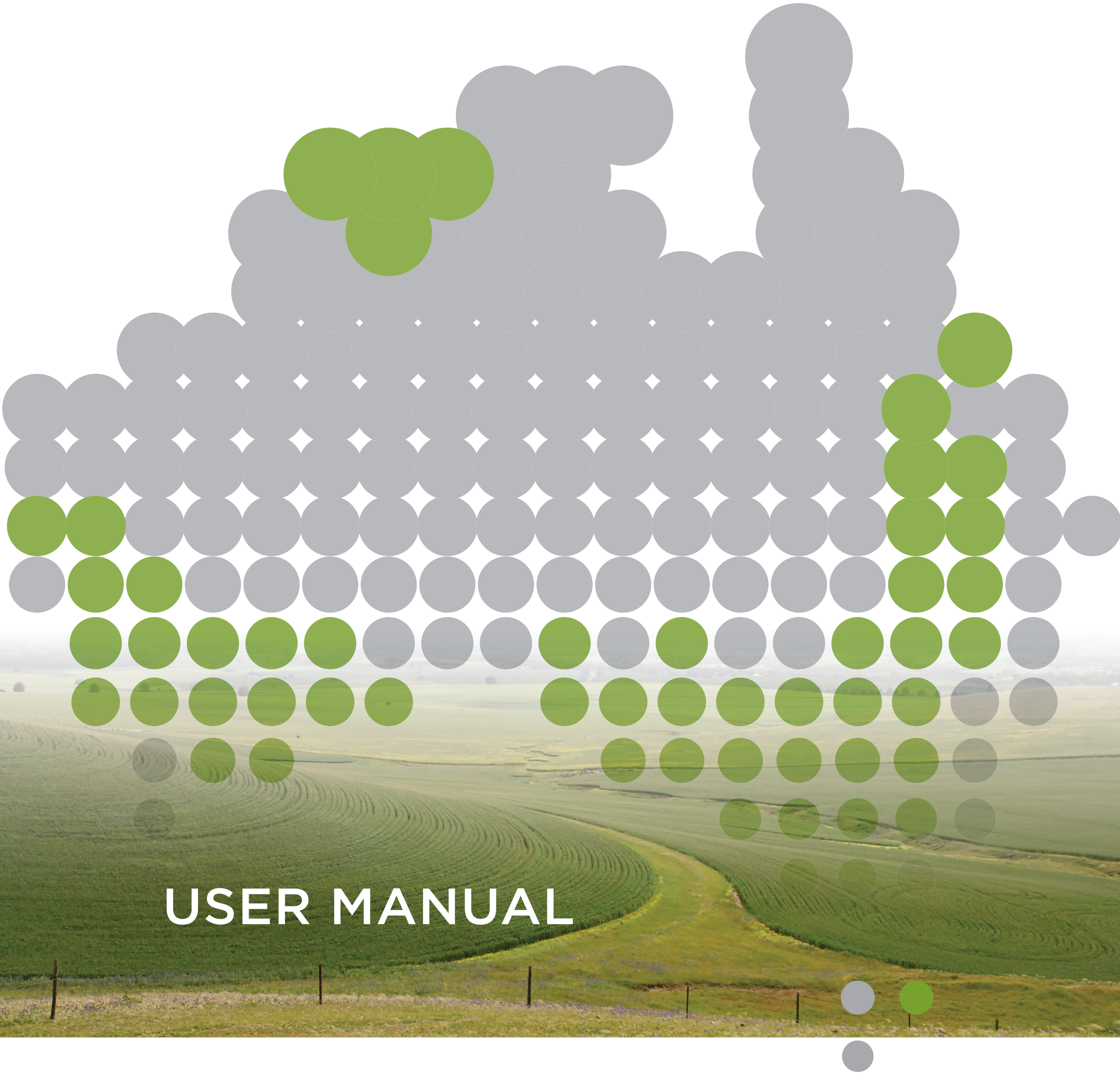

USER MANUAL

MAKING BETTER FERTILISER DECISIONS FOR CROPPING SYSTEMS IN AUSTRALIA

NSW GOVERNMENT Department of Primary Industries

GRDC Grains Research & Development Corporation

FIFA

NSW DEPARTMENT OF PRIMARY INDUSTRIES

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Acknowledgements

The database of historic nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) soil test–crop response trials for cereals, oilseeds and pulses established through the ***Making Better Fertiliser Decisions for Cropping Systems in Australia*** project (BFDC), and the ***BFDC Interrogator*** tool that was built to query the data, are being used to underpin all FERTCARE® fertiliser recommendations in Australia as *the best available data*. BFDC will also be used in the auditing of FERTCARE® accredited Decision Support Systems and FERTCARE® Accredited Advisors where these provide the basis for fertiliser recommendations in cereal, oilseed and pulse crops.

The user manual was written as part of the project to enable potential users of the ***BFDC Interrogator*** to understand, develop and use soil test–crop response relationships as part of soil test interpretation.

The *BFDC project* was supported by the Grains Research and Development Corporation. It was led by NSW DPI and includes substantial collaboration with the fertiliser industry (including the Fertiliser Industry Federation of Australia, International Plant Nutrition Institute, Incitec Pivot Fertilisers, CSBP, Summit Fertilisers, Impact Fertilisers, and Superfert), consultants (Back Paddock Company, Geographic Web Solutions, K I P Consultancy Services, Reuter and Associates, and Dodgshun Medlin), State and federal agencies (SARDI, DEEDI QLD, DAFWA, Vic DPI, TIA, and CSIRO), agribusiness (Landmark and Elders), and universities.

First published: March 2012

Edited: Hot Tin Roof Communications
Design and layout: Megan Hele Design

ISBN: 978 1 74256 269 8

MAKING BETTER FERTILISER DECISIONS FOR CROPPING SYSTEMS IN AUSTRALIA

BFDC INTERROGATOR

USER MANUAL

Instructions for using the *BFDC Interrogator* for examining State and regional calibration relationships and soil test criteria for single-year trials

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F I F A


Ben White

CONTENTS

Obtaining access to the BFDC Database 6

What is a calibration relationship? 7

Standardisation of soil test data 8

Interrogation procedure 8

Examining data in the calibration relationship 20

Longer-term trials 23

Appendices 24

- Appendix 1: Standardisation of soil test values 24
- Appendix 2: Soil $pHCaCl_2$ diagnostic 25
- Appendix 3: Relationships between PBI and PRI and PBC sorption tests 26
- Appendix 4: Classification of PBI status 27
- Appendix 5: Conversion of exchangeable potassium (mg/kg) to Colwell K (mg/kg) 28
- Appendix 6: Approximate relationship between Australian Soil Classification and Great Soil Groups 29

References 30

The Better Fertiliser Decisions Framework will make accessible all available fertiliser trial data across all Australian cropping regions.

Its success relies on you.

OBTAINING ACCESS TO THE NATIONAL BFDC DATABASE

To obtain access to the BFDC Database and *Interrogator*, users need to successfully complete a training course. Please visit www.bfdc.com.au for more information.

People attending the BFDC training courses will be given a temporary username and password to access the *BFDC Interrogator*.

After completing the course participants need to respond to the automated email they receive for ongoing access. The automated email is initiated through participant enrolment at the training course. Access via a more permanent username and password will normally be granted to those who have demonstrated responsible competency during the training course.

Simon Speirs, NSW DPI

WHAT IS A CALIBRATION RELATIONSHIP?

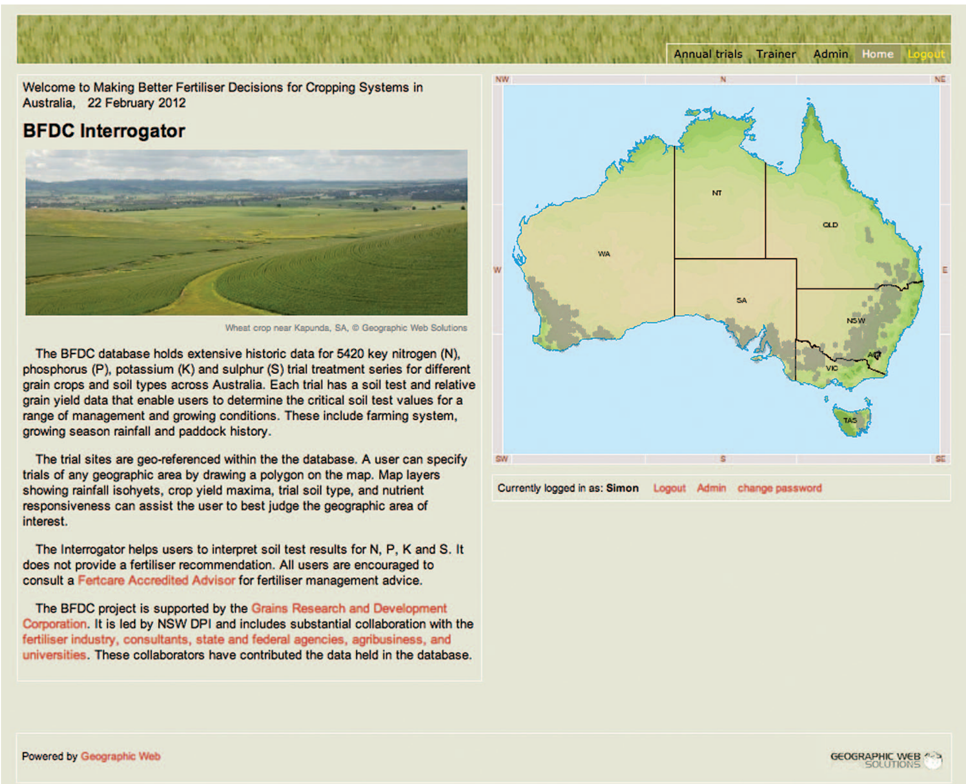
The BFDC Database contains data for more than 5000 soil test–crop response relationships carried out from the early 1960s to recent times.

The *BFDC Interrogator* (see Figure 1) is designed to create calibration relationships between a specific soil test (specified for depth of sampling and reporting units) and crop responses to an applied nutrient. The crop response to rates of applied nutrient is measured as the percentage relative yield (RY %).

Relative yield (RY) is defined as $(Y_0/Y_{max}) \times 100$, where Y_0 is the crop yield with no nutrient applied and Y_{max} is the maximum yield achieved in the trial after applying a specified nutrient.

Yield increase can also be shown for a selection of trials. Yield increase to applied nutrient, defined as $Y_{max} - Y_0$, is plotted against soil test values. This *BFDC Interrogator* option is typically more variable than plots presented using RY %, because growing season rainfall has large and variable effects on grain yield. A critical calibration relationship cannot be determined for yield increase using the *BFDC Interrogator*.

Figure 1. The *BFDC Interrogator* window



STANDARDISATION OF SOIL TEST DATA

For several soil tests, data held in the BFDC Database has been converted to valid equivalents to ensure the *BFDC Interrogator* has the capacity to generate additional calibration relationships or include a greater number of trials in a specific calibration plot. These conversions are defined in Appendices 1 to 5.

INTERROGATION PROCEDURE

After logging in go to the top of the page and select '**annual trials**'. This will take you to the main trial page with a map displaying all trial locations.

Initial selection

The soil test–crop response page enables you to make an initial selection of trials using the search criteria available (see Figure 2, page 9). The initial criteria you specify can include any one of the following:

- **Crop type or types (for example, wheat and/or barley, canola and/or rape)**
- **Nutrient (nitrogen, phosphorus, potassium or sulphur)**
- **Season (winter or summer crops)**
- **Farming system (dryland or irrigated)**
- **Soil type or types (Australian Soil Classification)**
- **Year or range of years**
- **Geographic region.**

Remember, the more criteria you set, the smaller the trial set derived from the first query.

You can group soil types and crop types by selecting multiple options in the drop-down menu (hold the Shift or Control key down to select the options you are seeking).

NAVIGATING THE MAP

To navigate the map, draw a 'zoom box' over the geographic area of interest (hold the left mouse button down and drag the cursor across the map). Other navigation tools are available by first choosing from the various options listed in the '**Map tools**' drop-down menu located below the map of Australia.

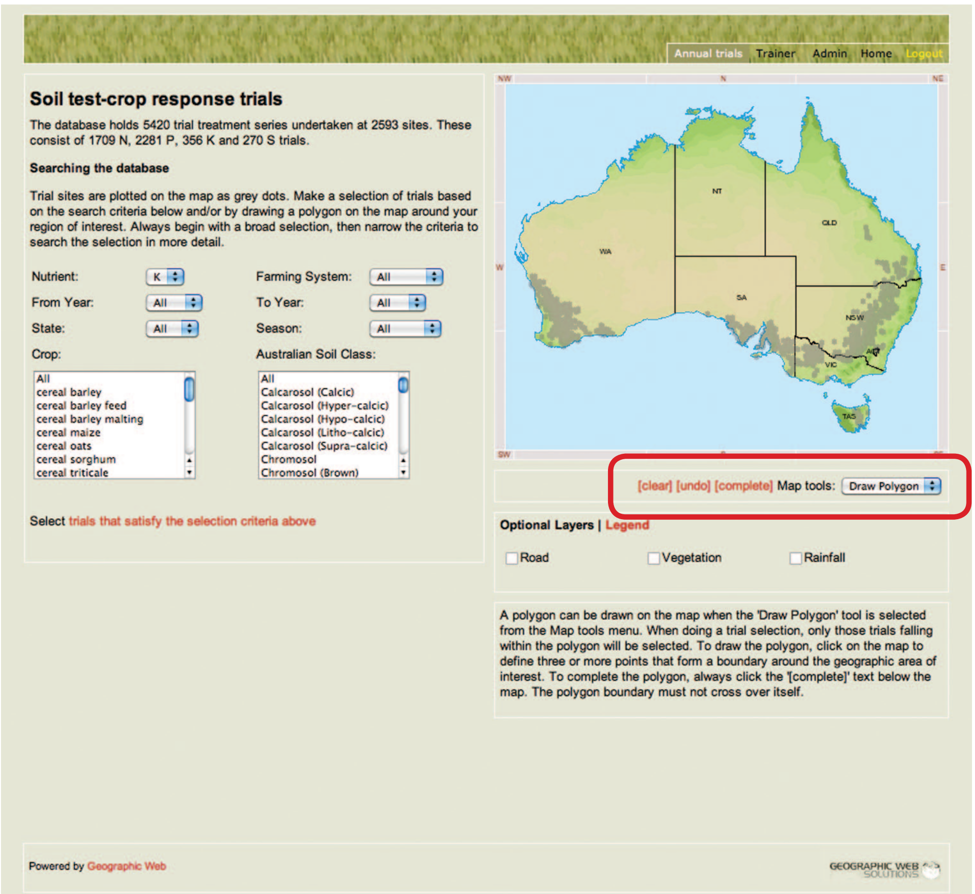
DEFINING A GEOGRAPHIC REGION

Using the '**Draw polygon**' tool, you can also select trials within a user-specified region.

To draw the polygon, make sure the '**Draw polygon**' option in the '**Map tools**' menu is selected. Click on the map at positions that enclose your area of interest (you will probably want to zoom in first). The first 'click' creates a point for the polygon and successive 'clicks' draw additional points and connecting lines. ***Do not allow polygon lines to cross over each other***. To complete the polygon, simply click on the text '**complete**' at bottom of map toolbar (see Figure 2). This will link the first point to the last point.

To clear the polygon at any stage, click '**clear**'. To go back one step, click '**undo**'.

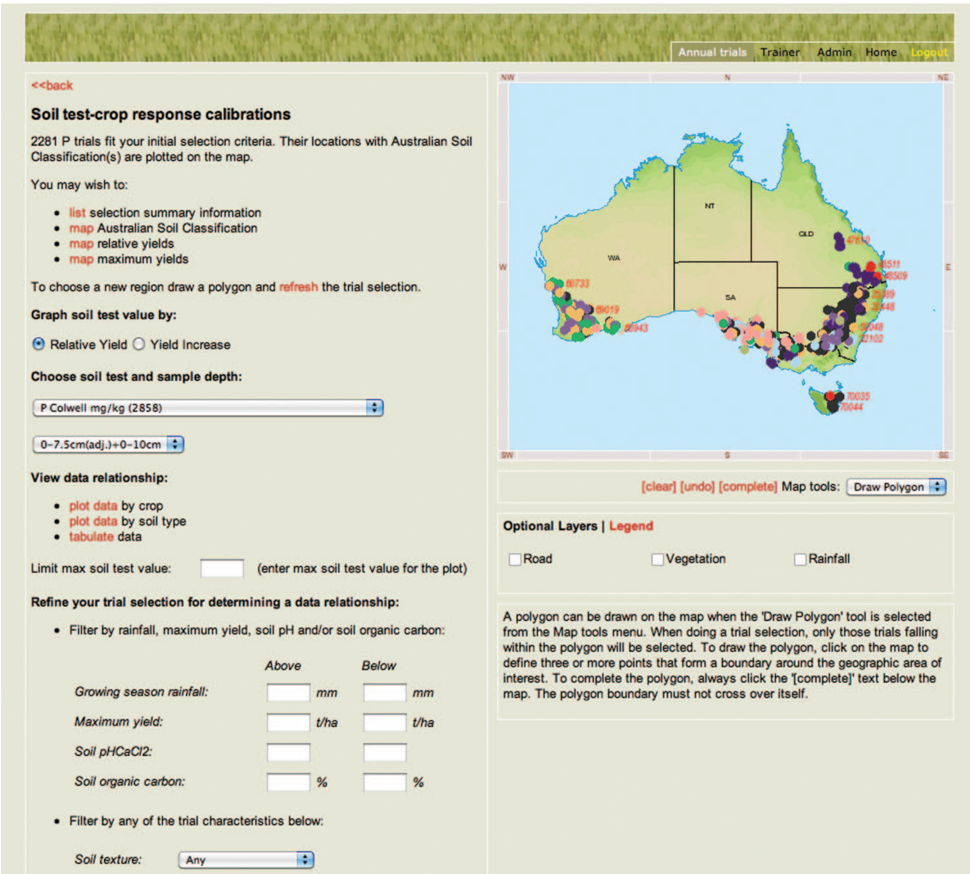
Figure 2. Soil test-crop response trials window



Starting the *Interrogation* process

To run any selected query, click on the link (see Figure 2, page 9): '**trials that satisfy the selection criteria above**' (in red type on left-hand side of screen). A new *Interrogation* form will appear indicating the number of trials that satisfy the initial query parameters and the trial positions will be plotted on the map as coloured dots (initially colour-coded for ASC soil types — assuming your data set has them) (see Figure 3).

Figure 3. Soil test — crop response calibrations window

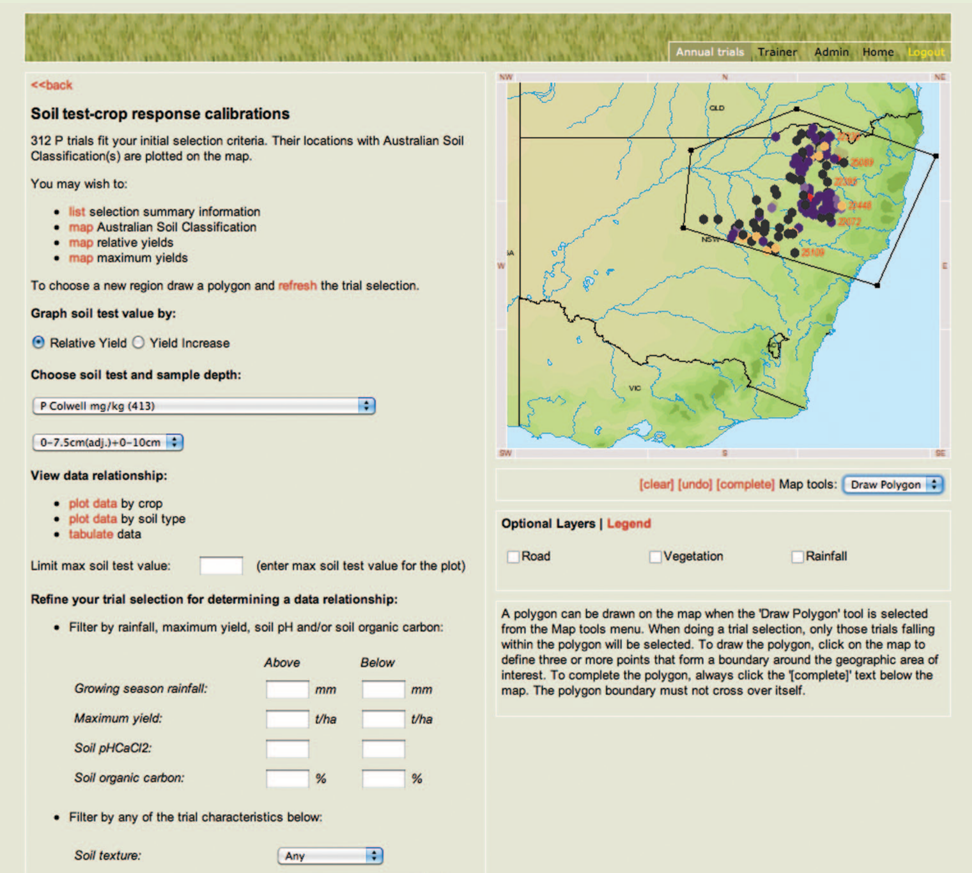


The polygon that defines the geographic area can be drawn in the soil test–crop response trials window before starting the interrogation process or in the soil test–crop response calibrations window:

a) **In the soil test–crop response trials window, choose the trials by clicking the link 'trials that satisfy the selection criteria above'. This will include only those trials that satisfy the non-spatial criteria and are found to fall within the polygon.**

b) **In the soil test–crop response calibrations window, the initial selection is based on the non-spatial criteria only. This allows the user to make a geographic sub-selection of the initial trial set. To do this, draw the polygon as earlier described and click 'refresh' (see Figure 4).**

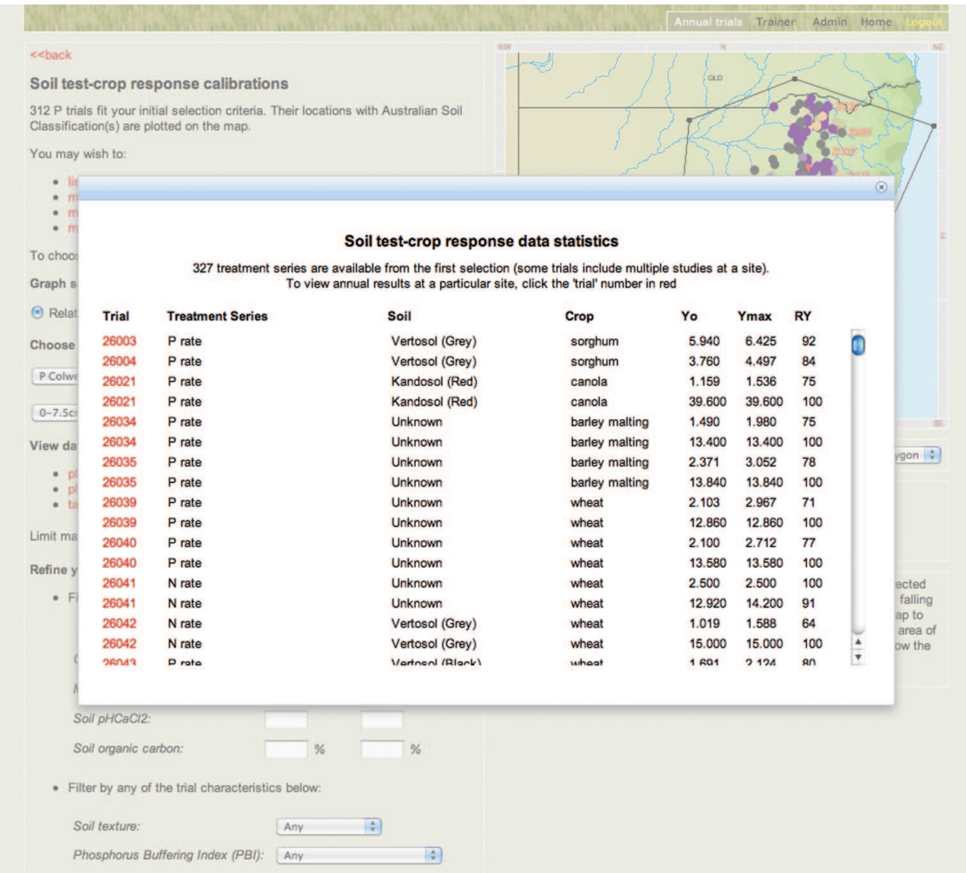
Figure 4. Using the polygon tool in the soil test-crop response calibrations window



OBTAINING A SUMMARY OF TRIAL DATA

To list summary descriptive and statistical information about each trial in the initial selection, click ‘**list selection summary information**’ (see Figure 5).

Figure 5. Listed information for soil test-crop response data statistics



VIEWING AN INDIVIDUAL TRIAL

To obtain detailed information about a particular trial, click the '**trial number**' in the summary table (see Figure 6).

Figure 6. Trial report

Trial 22340

Sown:	13 june 1968
Site:	2340
Location:	Eugowra NSW
Data owner:	NSWDII
Data custodian:	NSWII
Season:	winter
Farming system:	dryland
Experimental Design:	Nutrient Rate Factorial (eg N rates x P rates)
Crop:	cereal: wheat
Australian Soil Classification:	Unknown
Nutrient(s) studied:	P
Fertiliser Products used:	ammonium sulfate (NS) superphosphate single (PS)
Reference:	Holford ICR, Morgan JM, Bradley J, Cullis BR (1985) Yield responsiveness and response curvature as essential criteria for the evaluation and calibration of soil phosphate tests for wheat. Australian Journal of Soil Research 23, 167-180.

Soil Samples

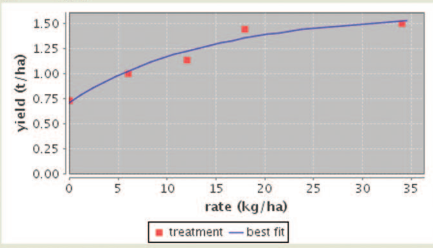
ID : 4521
Depth : 0-7.5cm
Timing : at sowing
Position : random
No Sub Samples : 20

Soil Test	Value	Units
P Ln PSI (Bach and Williams(1971) mod Holford	2.3	In L/kg
P in Soln (Holford data: method unknown)	1.5	mg/kg
P Exchangeable (Holford data: method unknown)	16.0	mg/kg
P Lactate Ca	9.2	mg/kg
P Lactate NH4	8.0	mg/kg
P Bray-1 pH3	11.0	mg/kg
P Bray-2 pH1	18.0	mg/kg
P Olsen	8.0	mg/kg
P Colwell	15.0	mg/kg
P Fluoride	15.0	mg/kg
P Truog	5.5	mg/kg
P Mehlich 1	18.0	mg/kg
P PBI (unadjusted)	27.0	
P Mehlich 3	22.0	mg/kg
P DGT Extractable	20.0	ug/L

Treatment Series Statistics

Treatment Series ID : 2927
Nutrient Studied : P
Time of Application : sowing
Nutrient Placement : drilled with seed
Row Spacing : 18cm
Product : superphosphate single
Treatment Means:

Nutrient Rate kg/ha	Yield t/ha	DM Harvest t/ha	Grain Protein %	Grain Water %	Grain Nutrient Uptake kg/ha
0	0.730				
6	1.000				
12	1.140				
18	1.450				
34	1.500				



Statistical Analysis:
Response Measured : mean grain yield (t/ha)
Statistical Model : Mitscherlich

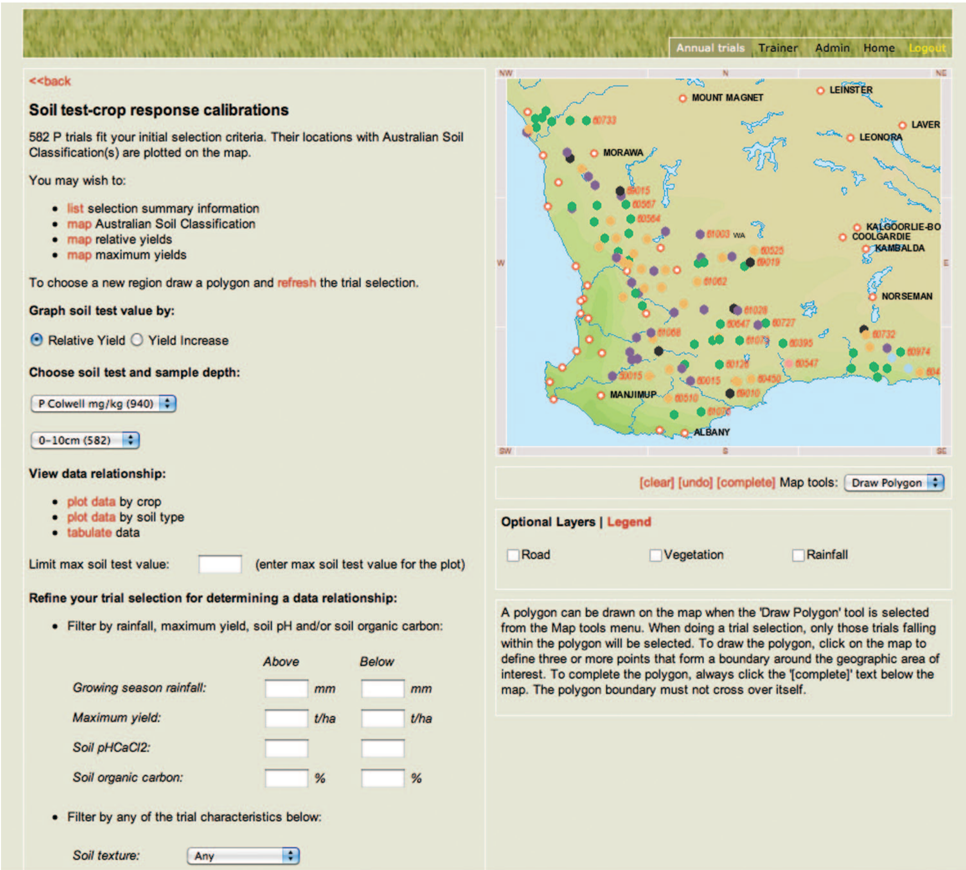
Coefficients	Statistics
A: 1.60545	Ftest:
B: 0.5527400000	100r2:
C: 0.0713400000	LSD 05:
Yo: 0.720	RY: 45
Ymax: 1.610	CV:

Comment : Most of them were located on red podzolics or solodics Most of the soils were sandy loam to clay loam, formed on shale, limestone, or granite. The alluvials and black earths were slightly heavier textured, cracking clays. The majority of soils were slightly to moderately acid (pH 5.2-6.5) with only the black earths in the alkaline range (pH 7.0-8.1). Soils varied in organic carbon from 0.9-3.0070, but the majority contained between 1.5 and 2.5% carbon. Wheat was sown in June or July with Heroncv. in most experiments, but, where sowing was later than mid July, Gamenya cv. was used. Harvesting with a Claas autoheader was carried out in the following December or January.

MAPPING TRIALS

Clicking any one of the three '**map**' links allows you to plot other colour-coded information about the trials on the map. These include % RY, Y_{max} and ASC (see Figure 7). To see what the colour codes mean for each parameter, click '**Legend**' below the map.

Figure 7. Mapped Australian Soil Classification for each of the selected trials



Developing a calibration relationship

To develop a calibration relationship for trials that fit your initial selection criteria, first select the soil test of interest and sampling depth.

When developing a calibration relationship:

a) **Always start with a large data set (for example, Colwell P at 0–10 cm) and study the calibration relationship before applying any filters.**

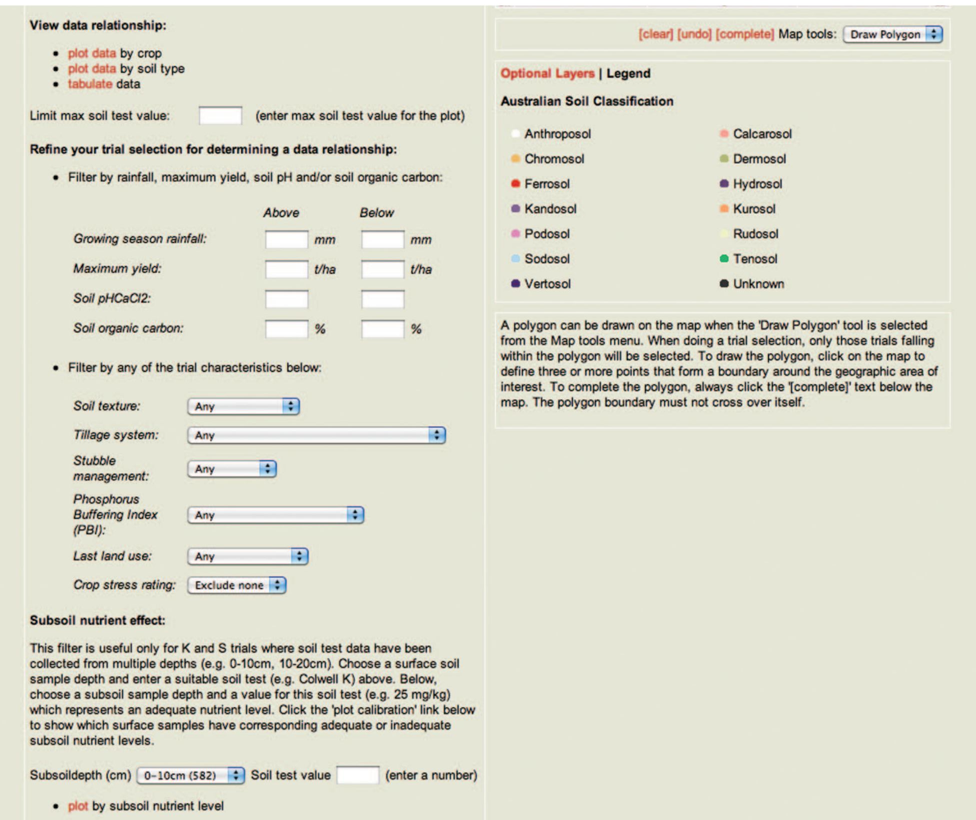
b) **Not all trials include data for all soil test methods, nor do all trials have soil test data for the different depths indicated in the drop-down menu.**

c) **A calibration curve cannot be fitted to yield increase data.**

Refine a calibration relationship by selecting filter options in the drop-down menus under the section of the page entitled '**Refine your trial selection for determining a data relationship**' (see Figure 8).

(Continued page 16) ....

Figure 8. Filter options available from the soil test–crop response calibrations window



▶ *(Continued from page 15)*

Refinement criteria act as data filters and include:

- **Maximum soil test value (limits maximum soil test value in plot).**

  Note: One *very* high soil test will cause other data points in the calibration plot to be compressed towards the Y axis.
- **Growing season rainfall (mm) (limits plot to a user-specified range).**
- **Y_{max} (t/ha) attained (limits plot to a user-specified range).**
- **Soil pH (limits plot to a user-specified pH range).**
- **Soil organic carbon (limits plot to a user-specified organic carbon range for the topsoil).**
- **Topsoil texture (limits plot to a specific soil texture).**
- **Tillage system (limits plot to a specific tillage system).**
- **Stubble management (limits plot to a specific stubble management system).**
- **Phosphorus Buffering Index (PBI) (plots to a specific PBI range).**
- **Previous year's land use (limits plot to a specific land use).**
- **Trial stress factor rating (excludes data from stressed trials).**

Use of these filters is optional. Applying one or more of them will typically exclude trials from a calibration plot.

Note: If a trial report does not include data in a given filter, the trial will automatically be excluded from a calibration plot.

When satisfied with the chosen options, click one of the two '**plot graph**' options:

a) Plot calibration by crop

b) Plot calibration by soil type.

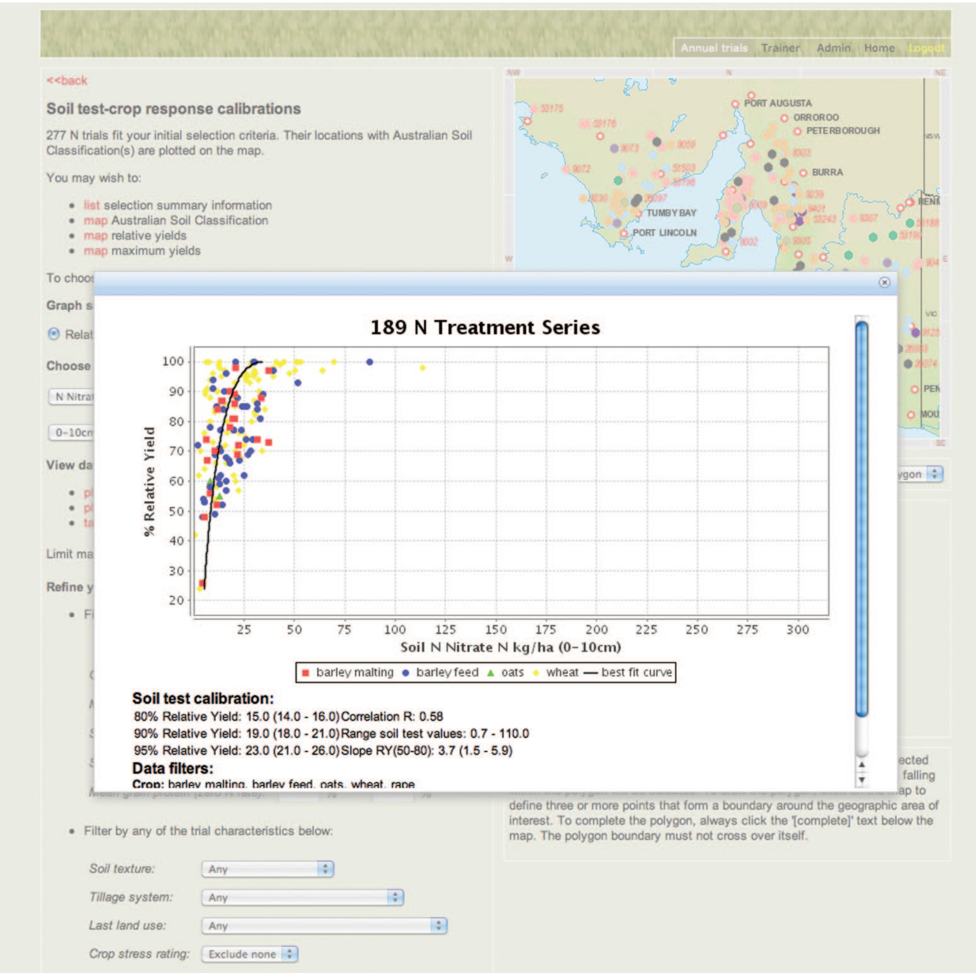
The calibration relationship (soil test value against % RY) will be displayed either for the selected crop type(s) or soil type(s).

Deriving soil test criteria

A calibration relationship will be plotted by crop or by soil type where the data rules are met. The calibration relationship will show the soil test critical values and ranges at 80, 90 and 95% RY. These will be displayed on the screen with the calibration relationship (see Figure 9).

(Continued page 18) ....

Figure 9. Soil test–crop response calibration relationship determined from 189 South Australian nitrogen treatment series for barley



(Continued from page 17)

Critical level — the point above which for the level of significance applied, RY is likely to be at least (or larger than) the nominated value.

Confidence range — based on the level of significance applied to the soil test–crop response curve, it represents the range of soil test values for which RY is likely to be at the nominated value. If the confidence range of two different calibrations are discrete (they do not intersect) the critical levels are different. For two calibrations where the confidence ranges overlap to a small degree, the critical levels still may be significantly different, but as the degree of overlap increases so too does the probability of the critical levels being the same.

Correlation co-efficient (R-value) — the correlation co-efficient is the measure of how well the calibration line fits the observations.

Range of soil test values — provides information about the lower and upper soil test values for the experiments included in the calibration.

Slope RY (50–80) — the value and range for this parameter is the slope (rate of change) of the calibration line between 50% and 80% RY as soil test value increases. A high value for this parameter suggests that increases in yield are large for increments of soil test value. This parameter provides information from which inferences about risk and economic gain from nutrient addition can be made. Generally this parameter is of most use in comparisons between calibrations sets.

Importantly, a calibration relationship cannot be obtained if one of the following rules is not applicable:

a) **A calibration relationship must have more than eight trials to be statistically valid.**

b) **A calibration relationship must have an R-value greater than 0.15.**

c) **A calibration relationship must have at least three trials in the 85–95% RY region of the curve. Fewer trials suggest a 'dumbbell' data distribution with a lack of data in the area of the most used critical levels.**

d) **The 95% confidence range must be less than half the estimate of the 95% RY.**

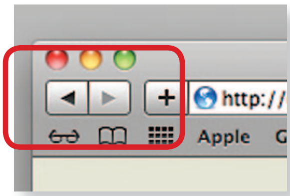
You can create a permanent record of your calibration relationship and soil test criteria by printing the graph (click '**print**' below the graph). Selecting this option will present the graph in a format that can be saved or printed from your internet browser.

Deriving a new calibration plot

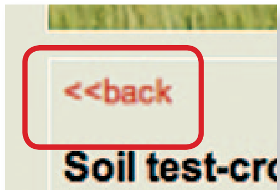
To develop a calibration plot using another set of trials or using different criteria (for example, different soil types or different soil tests, etc) first close the calibration window by clicking the '⊗' at top of graph window.

Then select the '**<<back**' option on the left-hand side of the page. Start deriving a new calibration plot by selecting another set of trials (for example, other crop type(s) and/or soil type(s) you wish to examine). Repeat the process as described above.

DO NOT select the toolbar 'back' button — this will take you back to the home page.



✗



✓

Notes

EXAMINING DATA IN THE CALIBRATION RELATIONSHIP

Impact of subsoil nutrient status

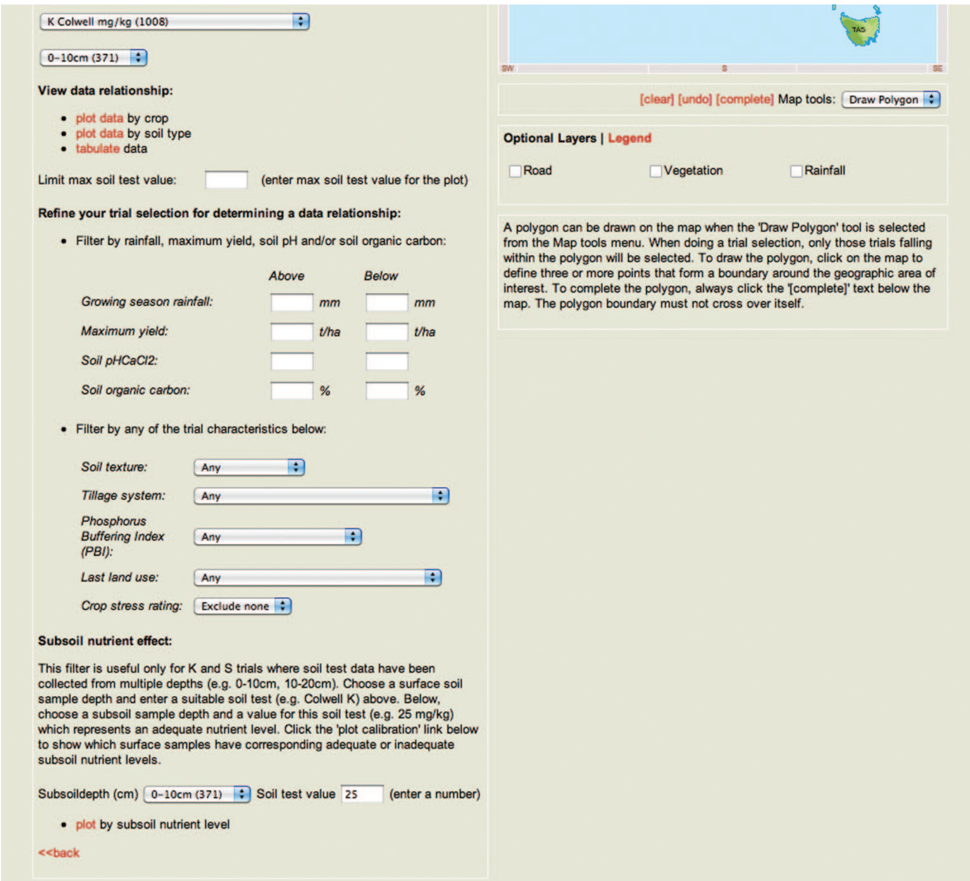
This filter is useful where trials have soil test data for multiple sampling depths (for example, 0–10 cm, 10–20 cm, etc) and it is specific to potassium and sulphur nutrient trials (see Figure 10). For example, crops growing on soil with adequate levels of potassium or sulphur in the subsoil may not respond to potassium or sulphur fertiliser applications, even though the surface soil layer itself may be nutrient deficient. You may explore this effect using the input boxes under the heading ‘**Subsoil nutrient effect**’.

By experimenting with different subsoil nutrient levels, you can discover the subsoil test value above which there is little point in applying nutrient.

To do this, choose a surface soil sample depth and a suitable soil test (for example, Colwell K) as usual in the boxes under ‘**Choose soil test and sample depth**’.

(Continued page 21) ....

Figure 10. Filter option using subsoil nutrient status

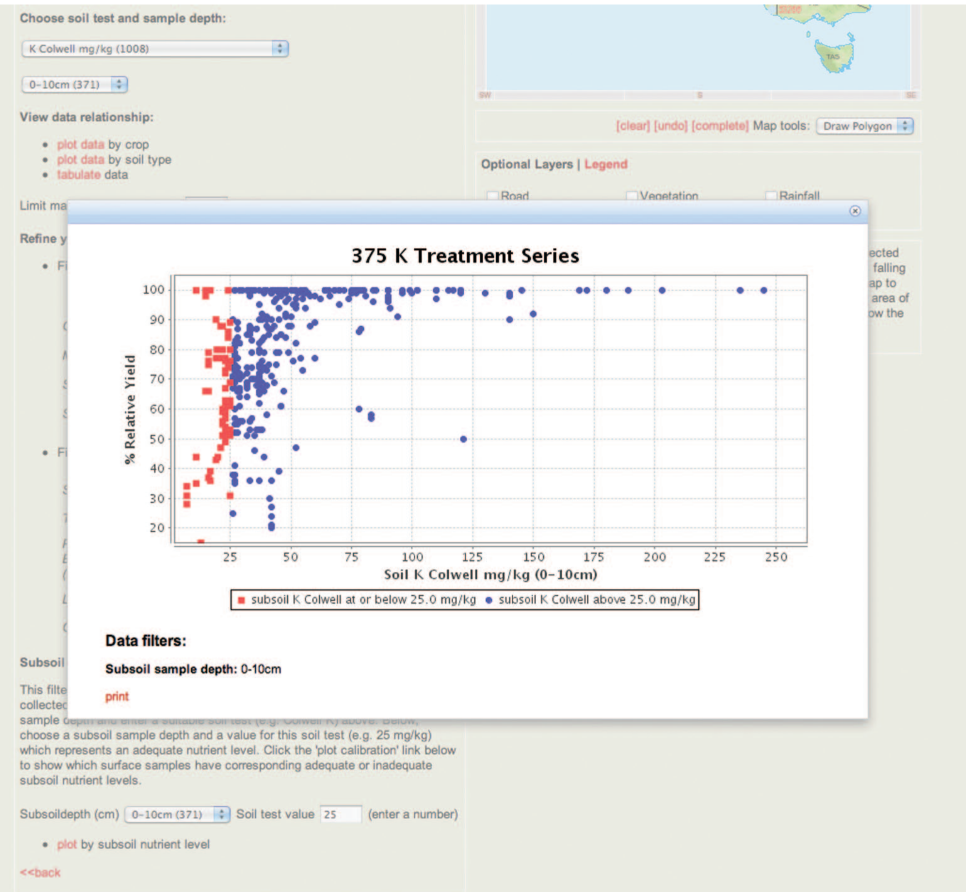


▶ *(Continued from page 20)*

Under '**Subsoil nutrient effect**', choose a subsoil sample depth and enter a value for this soil test that you think should be an adequate nutrient level for this depth. Then 'click' the '**plot by subsoil nutrient level**' link to show which surface samples have corresponding adequate or inadequate subsoil nutrient levels. The plot will display subsoil status in different colours (see Figure 11).

A calibration relationship cannot be developed using the 'Subsoil nutrient effect' filter.

Figure 11. Data displayed using the 'Subsoil nutrient effect' filter



Outliers

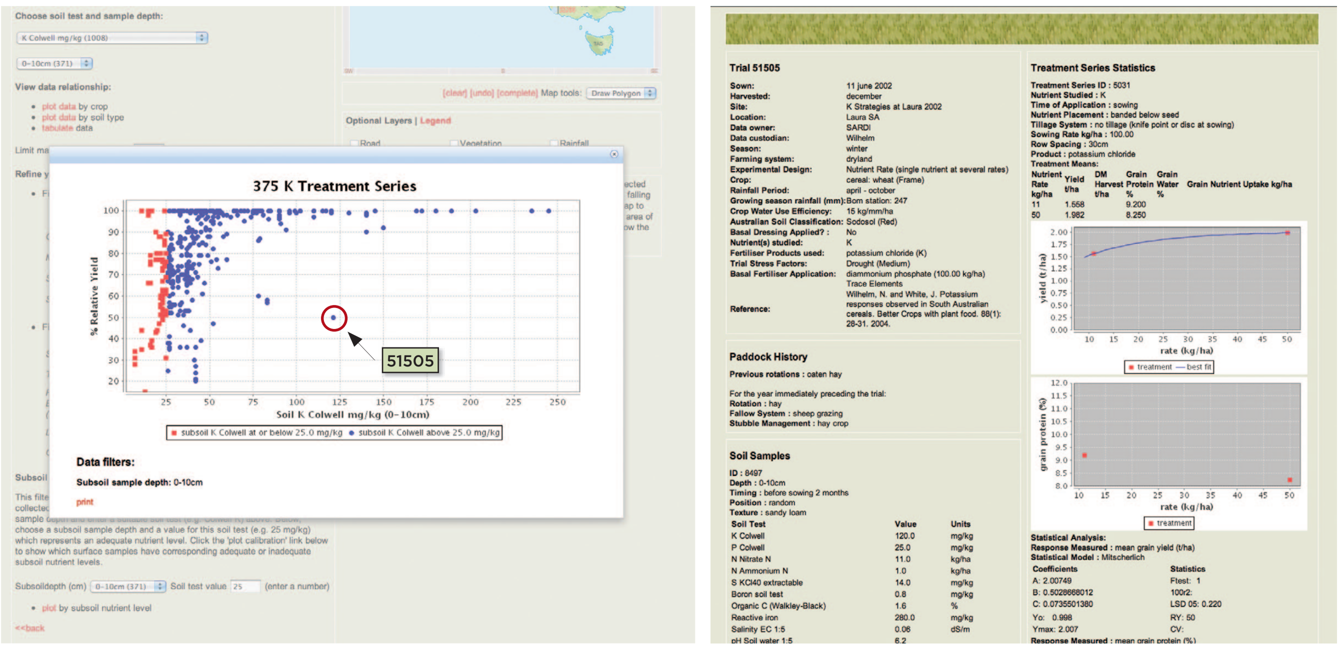
You may observe some trial outliers in the relationship generated. These are one or more data points in the calibration relationship that appear to be somewhat abnormal (displaced) when compared with the main body of data points.

You can investigate outliers by clicking on the data point in the calibration relationship or other presentation of the data (see Figure 12).

The trial report will be displayed and includes all data and meta data that has been entered for the particular trial, including the statistically fitted treatment series graph for crop yield against nutrient rate applied. The trial report will also display the individual mean treatment crop yields.

For trials where data for grain protein, grain nutrient or oil concentrations are entered, these parameters will also be displayed in the trial report.

Figure 12. Displaying trial report for an outlier



By investigating an outlier, you may find:

- **The fitted statistical relationship for crop yield and rate of nutrient applied does not seem correct and a different statistical fit for estimating Y_0 and Y_{max} may be more appropriate.**
- **A crop stress factor (for example, drought, disease or weeds, etc) may have limited yield response to applied nutrient.**
- **The soil type for the outlier may be atypical.**

There is no provision for arbitrarily removing outliers from the plot. If you are convinced any of the trial data should be excluded from the BFDC Database or that some data may require reviewing, then contact us at www.bfdc.com.au

LONGER-TERM TRIALS

Limited data for long-term trials has been entered into the BFDC Database. All long-term trial data entered is used in soil test–crop response calibrations only where each individual year can be treated as a single experiment.

Notes

APPENDIX 1

Standardisation of soil test values

The following soil test standardisations have been incorporated into the BFDC Database for access by the *BFDC Interrogator*, without compromising the original data.

Converting soil test data sampled to 0–7.5 cm into 0–10 cm depth by dividing the 0–7.5 cm values by 1.14 (Coad *et al.* 2010; K Peverill (pers. comm.). Thus, calibration plots can then be developed for 0–7.5 cm, 0–10 cm (unadjusted) and for 0–10 cm (adjusted).

Converting soil test data from consecutive depths (for example, 0–7.5 cm and 7.5–15 cm) where both soil test and soil bulk density have been recorded for each depth. These provide data for soil tests (nutrient concentration and content) to a converted depth of 15 cm.

Soil test units for soil cations have been converted to mg/kg from cmol(+)/kg and meq/100 g. The latter two units are equivalent.

Exchangeable or extractable potassium (K) (mg/kg) = cmol(+)/kg × 391

Exchangeable potassium (mg/kg) soil tests have been converted to extractable Colwell K (mg/kg) excluding vertosols with 2:1 clay lattices — see Appendix 5.

Soil pH tests in the National Database have been converted to pH $CaCl_2$ (1:5 soil:solution ratio) — see Appendix 2 for pH interpretations. Users can specify pH ranges they want to examine as an additional filter for say, interpreting a phosphorus (P) calibration plot.

All historical phosphorus sorption tests have been converted to the modern phosphorus buffering index (PBI) — (Burkitt *et al.* 2002) — see Appendix 3. PBI categories (from extremely low to very high) have also been defined as filters for calibration plots — see Appendix 4.

Soil carbon:nitrogen (C:N) ratios have been derived, using organic carbon (%) and total soil nitrogen (%) soil test values.

Estimates of *total soil mineral nitrogen available for crop growth* (mineral nitrogen at sowing *plus* nitrogen mineralised during crop growth from organic matter). The BFDC Database contains some estimates for 'in-crop mineralisation', either measured *in situ* or via various laboratory incubation tests. For these trials, calibration plots for total soil mineral nitrogen available for crop growth can be compared to mineral nitrogen reserves measured at sowing. However, in-crop mineralisation estimates are integral parameters of fertiliser nitrogen decision support systems (for example, Payne and Ladd 1993).

APPENDIX 2

Soil pHCaCl$_2$ diagnostic

Soil pH CaCl$_2$ ranges	Diagnostic interpretation
<4	**Highly acidic**
4–4.5	**Acidic** (possibly aluminium [Al] and manganese [Mn] toxicity and molybdenum [Mo] deficiency)
4.5–5	**Acceptable** for acid-tolerant species
5–6.5	**Optimal pH** for plant growth
6.5–7.5	**Neutral to slightly alkaline**. Often high in magnesium [Mg] and calcium carbonate ($CaCO_3$).
>7.6	**Alkaline** and includes sodic and salty soils

(see Table 7.2 from Slattery *et al.* 1999)

APPENDIX 3

Relationships between PBI and PRI and PBC sorption tests

State	No. soils	Regression	$100R^2$
WA*	133	PBI = -0.013 $(PRI)^2$ + 2.64 (PRI) + 15.1	93
Aust.**	290	PBI = 11.63 PBC (Ozanne and Shaw)	98
Aust.***	290	PBI = 10.78 PBC (Ozanne and Shaw) +12	97

Source: * Bolland and Windsor (2007); **PBI adjusted for Colwell P (Burkitt *et al.* 2002);
*** PBI unadjusted for Colwell P (Burkitt pers. comm.)

APPENDIX 4

Classification of PBI status

Phosphorus sorption status	PBI	PBC (O and S)	PRI
Extremely low	<15		<1
Very very low	15–35	<10	1–2
Very low	36–70	10–50	2–20
Low	71–140	50–100	20–50
Moderate	141–280	100–200	50–100
High	281–840	200–300	100–150
Very high	>840	>300	>150

APPENDIX 5

Conversion of exchangeable potassium (mg/kg) to Colwell K (mg/kg)

A large body of data from the *National Soil Fertility Project* carried out on cropping soils in Western Australia, South Australian, Victoria and New South Wales (Colwell 1979) were used to correlate and compare exchangeable potassium (Tucker 1974) and Colwell K (Colwell and Esdaile 1968) values.

Overall, the comparisons showed strong linear correlations, supporting a conversion ratio of **1:1**.

No comparative data was available for the Skene K test used mainly in Victoria.

The relationship was curvilinear for some low potassium soils from WA and slightly curvilinear at higher soil potassium levels.

A conversion ratio of **1:1** has been incorporated into the BFDC Database for all analysed soils, **except the 2:1 clay lattice soils**.

APPENDIX 6

Approximate relationship between Australian Soil Classification and Great Soil Groups

Australian Soil Classification (ASC)	Great Soil Groups	Northcote Factual Key
Calcarosols: soils that are usually calcareous throughout the soil profile (often highly calcareous).	Solonised brown soils, grey-brown and red calcareous soils, mallee soils, highly calcareous sands, lithosols, rendzina	Gc1, Gc2, Um1, Um5 soils
Chromosols: soils with a strong texture contrast between the topsoil and subsoil. Subsoils are not strongly acid and are not sodic.	Non-calcic brown soils, some red-brown earths red and brown podzolic soils, red and brown duplex soils	Many forms of duplex (D) soils
Dermosols: soils with structured subsoils that lack a strong texture contrast between the topsoil and subsoil.	Red gradational soils, prairie soils, chocolate soils, some brown, red and yellow podsolic soils, kraznozem, rendzina, chenozem, terra rossa	Wide range of Gn3 soils, some Um4 soils
Ferrosols: soils with a subsoil that contains a high content or free iron oxide and which lack a strong texture contrast between the topsoil and subsoil.	Krasnozems, euchrozems, chocolate soils	Gn3, Gn4, Uf5, Uf6 soils
Kandosols: soils that lack a strong texture contrast between the topsoil and subsoil, having at best a weakly-structured subsoil and not calcareous throughout.	Red, yellow and grey earths, calcareous red earths, earthy sands, brown podsolic soils or lithosols	Gn2, Um5 soils
Kurosols: soils with a strong texture contrast between the topsoil and strongly acid subsoil. These soils can have high levels of magnesium, sodium and aluminium in the subsoil.	Many podsolic soils and soloths	Many strongly acid duplex soils
Organosols: soils dominated by organic material.	Neutral to alkaline soils, and acid peats	Organic soils
Podosols: soils with a subsoil dominated by the accumulation of compounds of organic matter, aluminium and/or iron.	Podsols, humus podsols, and peaty podsols, lateritic podsols	Many Uc2, some Uc3, Uc4 soils
Rudosols: includes soils with little pedological organisation. These soils are usually 'young' in the sense that soil-forming factors have little time to pedologically modify parent rocks or sediments. The component soils can vary widely in texture and depth; many are stratified and some are highly saline.	Lithosols, alluvial soils, calcareous and siliceous sands, some solonchaks, deep gravelly soils	Uc1, Um1, Uf1 soils
Sodosols: soils with strong texture contrast between topsoil and subsoil horizons. These soils are not strongly acid but are sodic and have an ESP greater than 6.	Solodized solenetz and solodic soils, some soloths and red-brown earths	Many duplex soils
Tenosols: soils with generally weak pedological organisation in the subsoil.	Lithosols (shallow stony soil), siliceous and earthy sands, alpine humus soils and some alluvial soils, some terra rossa, brown earths	Many Uc and Um classes
Vertosols: clay soils with shrink–swell properties that exhibit strong cracking when dry. Some of these soils also show gilgai microrelief.	Black earths, black, grey, brown and red (cracking) clays	Ug5 soils

Source: Adapted from Isbell 1996, Peverill *et al.* 1999 and Hall *et al.* 2009.

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Notes

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