ONTARIO

Understanding the Science Behind Fertilizer Recommendations

By T.W. Bruulsema

Geographic and statistical analysis of crop nutrient response databases can be used to build confidence in recommendations and encourage appropriate interpretations of soil tests.

Crop producers often question the relevance of soil fertility recommendations, despite a long history and large volume of soil test calibration research. They question whether the soils they manage and the cultivars they grow are represented in the research backing the recommendations. The link between the recommendations and the research is often lost, or unclear if the data are not systematically organized.

Predicting crop response to applied nutrients remains a challenge, even after many decades of research. Soil tests effectively distinguish soils with low and high probabilities of crop response for most nutrients. However, they address only a small part of the variability in crop response that occurs across sites and years.

The reasons why soil tests fail to do better are known, but are not often quantified to a degree suitable for use in soil fertility management. Factors such as soil texture, yield potential, specific weather conditions, and cultivar differences obscure a clear relationship between soil tests and crop responses.

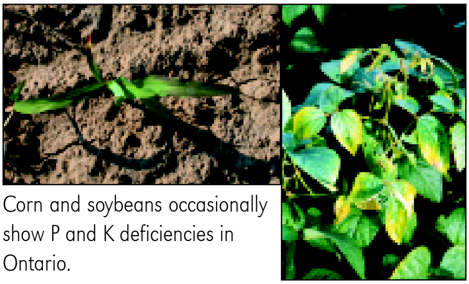
Recommendations may or may not include allowances for some of the foregoing factors. The soil test calibration database may be missing data on these factors. Filling in these missing data demands investment of effort, but the effort can be worthwhile. A couple of examples, drawn from two databases—on phosphorus (P) for corn and potassium (K) for soybeans in Ontario, Canada—are provided here to demonstrate the educational and practical value of such analyses.

Spatial Distribution

The distribution of the corn and soybean crops in Ontario, and the sites included in the databases of responses to nutrients applied in field trials, are illustrated in **Figure 1**. These maps show the locations of 99 site-years of trials evaluating corn responses to P, and 128 site-years for soybean responses to K. The research represented was conducted by many soil fertility research scientists over the past four decades.

The crop areas cultivated today extend considerably to the north and east beyond the area represented in the field trials, particularly for the soybean crop. Nevertheless, the areas of most intensive production coincide with the most intensive areas of field trials.

Maps such as these allow producers to reference their own site with respect to the sites included in the databases. This in itself could enhance their acceptance of the recommendations derived.



Corn and soybeans occasionally show P and K deficiencies in Ontario.

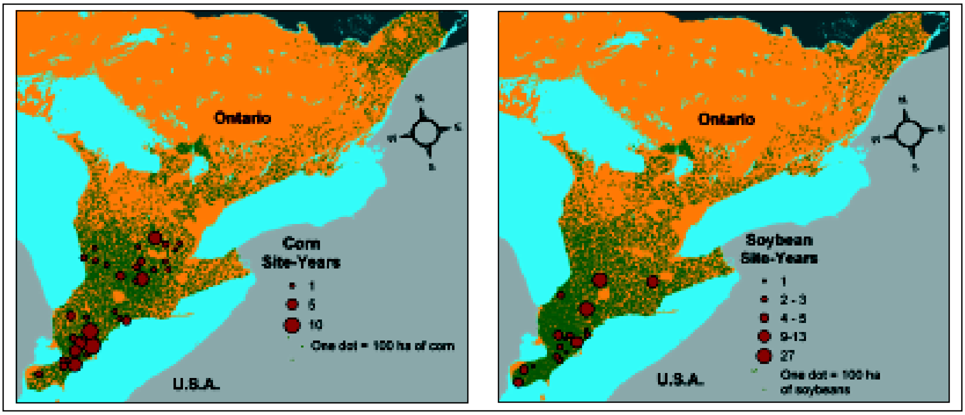


Figure 1. Distribution of corn and soybean production areas and soil fertility field trial sites in Ontario, Canada.

Mapping response parameters for each site also allows the analysis of spatial trends. Visually, no clear trends made themselves apparent. The number of sites limited the expectation of identifying such trends. Sites separated even by small distances differed considerably in soil texture. For these reasons, the analysis of the data focused on measured parameters at each site. For larger databases, geostatistical analysis could potentially identify sub-regions where response frequencies differ, or where the relationships between soil test level and crop response differ.

Impact of Soil Test Level

These databases contain sufficient data to calculate an optimum[1] rate for each site-year, using linear, quadratic, and exponential response models. Where the optimum rate was zero, the site was designated non-responsive. The frequency of responsive sites estimates the probability of crop response. The number of replications varied among site-years. Multiple levels of other factors such as tillage or cultivar resulted in very high levels of replication for some site-years: up to 60, with a median of 10, in the corn database, and up to 96, with a median of 4, in the soybean K database. All analyses across site-years used number of replications as a weighting factor.

Summarizing the response characteristics by existing soil test categories alone, **Table 1** indicates that both probability of response and mean optimum rate decreased as the soil test levels increased. Comparing response probabilities, one can conclude that applying P to corn is more critical than applying K to soybeans. Higher soil test levels imply lower probabilities of response. However, many producers would consider a 15 to 25% risk of yield loss worthy of attention, particularly if they can eliminate it with a low rate of well-placed fertilizer.

The analysis by soil test level presented in **Table 1** explained only 17% of the variability in optimum rate of P for corn and 13% in that of K for soybeans. If one applies the mean optimum rates shown at any given soil test level, there is a very high risk of applying either too much or too little. Since at lower soil test levels, the risk and size of potential yield loss is high, recommendations are usually higher than the mean optimum rates shown.

Conversely, at higher soil test levels, some recommend applying no nutrient because potential yield losses are rarer and smaller, and the amount of nutrient required is less than can be applied with typical field equipment. However, if

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[1] "optimum" in this article means the most economic rate calculated from the response function (considering only the current season and not future crops) using prevailing prices for fertilizer and crop.

Table 1. Corn and soybean response characteristics in four soil test categories[1].

Soil test level[2]	Corn Probability of response, %	Corn Mean optimum P_2O_5, rate, lb/A	Soybeans Probability of response, %	Soybeans Mean optimum K_2O rate, lb/A
Low	85	45	44	48
Medium	59	25	49	35
High	19	7	15	12
Very high	25	7	24	10

[1] Based on 99 and 128 site-years of data for corn and soybeans, respectively. Analysis was weighted based on number of replications involved in each site-year.

[2] Soil test levels dividing the four classes for corn are 9, 20, and 30 parts per million (ppm) Olsen-P, and 60, 120, and 150 ppm ammonium acetate K

maintaining soil fertility is valued, then the substantial probability of crop response provides added justification for fertilizing at moderate levels in soils testing high to very high. Controlled placement of low rates using techniques such as seed-placed high P starters makes sense as a fertility management strategy for corn in these situations. Neither of these two databases contain sites with soil tests exceeding the "very high" level. For sites where such levels have been attained, these databases provide no guidance to the question of whether a starter fertilizer continues to have any value.

Impact of Soil Texture and Yield Potential

Although the soil test explains only 13 to 17% of the variability in optimum rates, that does not imply it has no value. Sites vary widely in soil test levels, and the differences in response probability and optimum rates make soil testing an economically favorable practice. However, these figures suggest an opportunity to gain considerably more by finding other factors that predictably influence the optimum rate. To date, only soil texture and yield data are factors that are reliably represented in these two databases. Yield potential is taken as the highest mean treatment yield.

When soil texture classes are taken into account, the coarser textured soils appear to have higher optimum levels of P for corn, compared to finer textures (**Table 2**). Adding soil texture to the analysis doubled the total variability explained, to 33%. However, the database contained no sites with coarser textured soils at high and very high soil test levels. Yield levels for this database averaged 132 bu/A, but the effect of yield on optimum rate was not significant ($p=0.2$).

Soil texture class influenced optimum rates of K for soybean as well (**Table 3**). Soils of finer texture appear to require more K for a given soil test level. Yield also had an influence, with optimum rate of K_2O increasing by 1.1 lb/A for each bu/A of increased yield. Mean soybean yield in the database was 43 bu/A. The combined effects of soil test level, soil texture class, and yield explained 23% of the variability

Table 2. Impact of soil texture class on mean optimum rates, in lb/A, for P_2O_5 applied to Ontario corn.

Soil test level	Soil texture Sandy to loamy	Soil texture Loamy to clayey
Low	70	42
Medium	46	16
High		7
Very high		7

Table 3. Impact of soil texture class on mean optimum rates, in lb/A, for K_2O applied to Ontario soybeans.

Soil test level	Soil texture Sandy to loamy	Soil texture Loamy to clayey
Low	50	
Medium	16	45
High	0	13
Very high	2	14

in optimum rate.

The examples in **Tables 2 and 3** show that the prediction of optimum rates from soil tests can be substantially improved by considering other factors specific to the site. But with only 23 to 33% of the variability explained, there is considerable room for improvement.

Weather is one of the most important modifiers of the relationship between soil test level and crop response. However it is difficult to determine which weather data are most representative of its influence. And even if the relationship could be deduced from these databases, the predictive value will be dependent on predicting weather.

A larger database on corn responses to nitrogen (N) is currently under review in Ontario. It includes 595 site-years of field trials with at least three rates of N. While this database did not include a soil test, an analysis found four factors—yield, preceding crop, soil texture, and application timing—explained about 28% of variability in optimum rates. A considerable amount of variability, resulting from weather and other factors, remains unexplained.

Conclusion

Even the best soil test calibration databases explain less than a third of the variability in crop response to added nutrients. This has implications for the agronomic interpretation of soil tests. It implies that there is not a single optimum rate for all producers with similar soil fertility. Rather, the optimum rate depends on the relative magnitude of risks being faced by each particular producer.

Fertilizer rate decisions are risk management decisions. Agronomically, the risk of a nutrient limiting crop yield must be balanced against cost and impact on the balance of nutrient levels in the soil. Environmentally, added risks of impacts on water or air quality must be brought into consideration.

When regulation mandates nutrient rate reductions, yield losses will vary among producers. The risk of yield loss will be only partly predictable. Site-specific assessment of both the agronomic and environmental risks is needed to determine a rate of nutrient application that maximizes its beneficial use. BC

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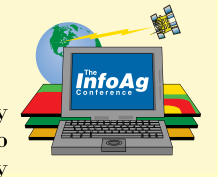
InfoAg Ohio Valley Regional Conference August 16-17



"Equipping Today's Agriculture with Technology" will be the theme of the InfoAg Ohio Valley Conference, planned for August 16-17, 2004, at Clark State Community College in Springfield, Ohio. This is the first in an expected series of regional Information Agriculture Conferences modeled after the popular InfoAg Conference series organized by PPI/PPIC/FAR.

University and industry experts will share real-world experiences and successes with technology to help crop and livestock producers adjust to the demand of changing agriculture. The Ohio Valley event is jointly presented by PPI/PPIC/FAR, Ohio Agriculture Technology Association, Ohio Geospatial Extension Program, Ohio State University Extension Precision Agriculture, Ohio State University Extension Beef Team, Purdue University Site-Specific Management Center, University of Kentucky Precision Resource Management Team, and Kentucky Precision Ag Network. For more about the InfoAg Conference, visit these websites: >**www.farmresearch.com/infoag**< or >**www.ppi-far.org**<. BC