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# International Section

## Soil Testing: A Proven Diagnostic Tool

By Sam Portch and Mark D. Stauffer

**Soil testing is being under-utilized in the developing world, but data show it puts money in farmers' pockets even when the relatively high cost of a complete analysis is considered. Developing the system to truly meet a farmer's needs is both practical and feasible.**

It is difficult to determine who exactly began the science of soil testing. Certainly, Europeans such as Justin von Liebig, famed for the Law of the Minimum, and Jean Baptiste Boussingault, sometimes referred to as the father of modern agricultural chemistry, would be candidates as founding fathers. Since then, several scientists during the late 1920s and early 1930s, including those well known by their analytical methods such as Bray, Morgan, Spurway, and Truog, advanced soil testing by showing the importance of measuring labile or available rather than total plant nutrient contents. In terms of service, one of the earliest laboratories established to analyze large numbers of farmers' samples was developed in the early 1940s by J.W. Fitts in Nebraska.

Today, around 4 to 5 million (M) soil samples are analyzed annually in North America alone, in both private and state operated facilities. While this is an impressive number, it still falls short of being adequate for the region's large cultivated area. If one looks outside North America, it is clear that soil testing is even more underutilized as a diagnostic tool. The most frequently noted reasons are discussed within this article along with points to consider for improving its application.

### Common Pitfalls

The first issue is that many laboratories throughout the world routinely offer an incomplete assessment of soil fertility, providing only an analysis of pH, organic matter, some form of nitrogen (N), available phosphorus (P), and potassium (K). Data from China (**Table 1**) illustrate this problem as the prevalence of secondary and micronutrient deficiencies in a number of soils obviously means that a large percentage of soils were not receiving adequate analyses—at least 49% if one considers only zinc (Zn). But given the range of deficiencies, at least 70 to 80% of these soils were inadequately assessed until a complete analysis was done. Unfortunately, the same can be said for research results based on incomplete soil analysis. Based on **Table 1**, greater than 50% of

### Soil testing at

Bathalagoda Research Station in Sri Lanka showed the need for K fertilizer. Application of K fertilizer resulted in 1 t average yield response over three consecutive rice crops.



**Table 1.** Results of 140 greenhouse trials based on soil analyses with soils from 17 provinces of China (relative dry yield matter with optimum [OPT] as 100 %).

| Nutrient omitted from OPT | # soils showing deficiency, % of total 140 | Range of relative yield, % | Average relative yield, % |
|---------------------------|--|----------------------------|---------------------------|
| -N                        | 137 (98%)                                  | 6.1 to 83.9                | 45.2                      |
| -P                        | 126 (90%)                                  | 8.5 to 89.7                | 39.6                      |
| -K                        | 84 (60%)                                   | 39.0 to 89.8               | 73.5                      |
| -Ca                       | 20 (14%)                                   | 2.2 to 89.0                | 52.8                      |
| -Mg                       | 25 (18%)                                   | 34 to 89.7                 | 74.7                      |
| -S                        | 45 (32%)                                   | 14.0 to 89.8               | 71.3                      |
| -Fe                       | 17 (12%)                                   | 46 to 87.5                 | 79.4                      |
| -B                        | 36 (26%)                                   | 65 to 89.7                 | 80.9                      |
| -Cu                       | 37 (26%)                                   | 40 to 89.5                 | 77.2                      |
| -Mn                       | 34 (24%)                                   | 50.2 to 89.5               | 79.1                      |
| -Mo                       | 28 (20%)                                   | 38.7 to 89.4               | 79.5                      |
| -Zn                       | 68 (49%)                                   | 40.0 to 89.6               | 75.1                      |

research using only N, P, and K analyses would give misleading, lower than optimum yield results.

Incomplete analyses lead to the next reason for under-utilization of soil testing—that being popularization of **generalized,**

**low yielding fertilizer recommendations.** Continued mischaracterization of soil fertility status sets up a feedback loop wherein researchers can only obtain misleading, suboptimal results. The failure of researchers to scrutinize their individual trials sufficiently results in the pooling of poor data with good data. Setting reasonably high yield goals for each trial could help researchers distinguish between good and poor data. Low yielding trials should undergo further study to determine why they performed poorly. If the trial had excessive insect damage, incorrect analysis, poor weather or management, etc., the data should not be pooled with other valid data. Thirdly, years of research and observations by the authors, particularly in developing countries, has led to the conclusion that conservative recommendations—to help the farmer reduce his fertilizer costs—often reduce his income substantially by inefficient utilization of all inputs, including fertilizers. Little or no thought is given to the opportunity cost of under-utilized yield potential.

**Slow service** is probably the worst deterrent preventing farmer use of soil testing services. Returning fertilizer recommendations to a farmer long after samples were taken from the field minimizes the benefit, giving the entire concept of soil testing a bad reputation. Recommendations have little meaning to the farmer if the crop for which they were required is already planted (although the soil test results are useful for future nutrient management). Slow service is most apparent in developing countries where a turn-around time of less than one month is exceptional. In countries where two or three crops are grown per year, faster service is essential. A maximum of 7 to 10 days would be acceptable; anything longer detracts from the service.

**The last common concern is cost of the service.** Subjecting a soil sample to a ‘complete’ analysis involves 12 to 14 determinations and calculations. The cost of this varies from country to country, but an individual sample would cost between US\$12 to US\$20, including the report with recommendations. This is often out of range for many resource-

Three reasons why many generalized fertilizer recommendations result in low yields:

- a) Many misleading research results have guided researchers this way;
- b) Pooling of poor data with good;
- c) An inherent feeling that conservative recommendations save farmers money by reducing fertilizer input costs without looking at lost profit.



In Tibet, the balanced fertilization plot (at left) showed great response for barley compared to the local recommended practice (at right).

joining farmers to consolidate their fields and develop a shared recommendation of fields with similar landscape, soil type, crop, management, and yield goals. Farmer cooperatives might develop a seasonal field sampling rotation that produces a common recommendation for a small number of fields. Thus, analysis cost can be spread amongst a large number of farmers, but still have an applicable area.

Some may say soil testing is not a worthwhile endeavor, particularly in developing countries. However, the potential benefits from more definitive research results and recommendations require that one must look for ways to develop sound soil testing systems. How could this be done?

**The first goal should be increased awareness** (from administration to technician-level) about the problems mentioned. Strategies to overcome these problems will no doubt follow. The main objective is to regard soil testing as more than just the ‘bricks and mortar’ of a laboratory. A complete program provides: sampling and sample handling, the laboratory, local research and data interpretation, dynamic recommendations, plus education and extension in all the above.

### **Benefits from an Optimized Soil Testing Service**

Where reliable soil testing is being used, many successful and profitable research- and farmer-oriented results are produced. One of the most recent and convincing examples comes out of the Bathalagoda rice research station in Sri Lanka. Prior to intervention, six consecutive seasons of N, P, and K research on rice failed to show any need for K fertilizer. Secondary and micronutrient deficiencies were not being addressed, hence, only low yields were obtained. After a complete soil test, magnesium (Mg), sulfur (S), boron (B), and copper (Cu) were included in all treatments along with variable rates of N, P, and K. The result was a 1 tonne (t) average yield response to K over three consecutive rice crops. Seasonal yields ranged between 5.3 and 6.2 t/ha when all yield-limiting nutrients were applied. Higher yields are almost certainly possible using this knowledge to adjust other agronomic practices.

Many observations in India show higher, more profitable yields when fertilizer programs are based on complete soil analyses. Data often illustrate that recommendations made by many of the state scientists are too conservative. In northern India, highly significant yield increases in pea (450 kg/ha) and chickpea (1,390 kg/ha) were obtained when soil test-based treatments were compared to generalized state recommendations (**Table 2**). Significant responses to P and K were obtained with both crops (data not shown) and, in both crops, further additions of S and Zn greatly increased yield over treatments supplying only N, P, and K. The

poor farmers, especially those managing a fraction of a hectare. The burden to the farmer could hopefully be lessened through either analyzing a larger volume of soils, thereby reducing the cost per sample or by subsidy made available by government or the ag retailer as part of a customer service package. In the case of small holders, one successful compromise has been to encourage ad-

influence of manganese (Mn) and B (data not shown) were also positive in both cases, but only statistically significant in the pea crop.

Farmers at five locations in eastern India used soil test-based fertilizer recommendations to produce more profitable rice crops (**Table 3**). Interestingly, the average loss was less when farmers used their own fertilizer program instead of the state recommendation, but both were far less profitable than soil test-based recommendations.

In the highlands of Tibet, research trials with barley and wheat showed significantly higher yields using soil test-based recommendations compared with present farmer practice. Yield increases were 1,733 kg/ha with barley and 493 kg/ha with wheat. These gains provided extra farmer profit of US\$313 and US\$83/ha, respectively. Two unreplicated demonstration trials with the same crops in nearby locations produced similar results.

Throughout Asia, networks of unreplicated, multi-located field demonstrations provide an effective means of showing farmers that soil test-based recommendations are more profitable than either state recommendations or their own current practices. Most results remain unpublished despite their influence on common practice. For example, the average cost of fertilizer for the soil test-based treatment for mustard in eastern India was US\$84/ha...higher than the state recommendation (US\$43/ha) or the farmer practice (US\$59/ha)...but the increased profit resulting from its application was US\$183 over the state recommendation and US\$149 over the farmer practice (**Table 4**). Conservative recommendations clearly do not help farmer profitability.

Results from two pomelo demonstration trials in the Fujian Province of China showed soil test-based yields averaged 7 t/ha over the current farmer practice and was US\$870/ha more profitable. In two banana demonstration trials in the same province, an average increased profit of US\$540/ha was obtained using the soil test-based recommendations compared with current farmer practice. Similar comparisons with citrus at three locations in Hubei Province increased farmer

**Table 2.** The effect of different fertilizer treatments on selected treatments in trials with pea and chickpea in northern India.

| Crop                     | Treatment  | Grain yield, Straw yield, |       |
|--------------------------|--|---------------------------|-------|
|                          |  | kg/ha                     | kg/ha |
| Pea                      | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>20</sub> Mn <sub>10</sub> B <sub>5</sub> | 3,200                     | 4,470 |
|                          | State recommendation   | 2,750                     | 3,870 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>0</sub> Zn <sub>20</sub> Mn <sub>10</sub> B <sub>5</sub>  | 2,900                     | 4,000 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>0</sub> Mn <sub>10</sub> B <sub>5</sub>  | 2,920                     | 4,020 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>20</sub> Mn <sub>0</sub> B <sub>5</sub>  | 3,000                     | 4,170 |
|                          | C.D. 5%  | 137                       | 182   |
| Chickpea                 | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>20</sub> Mn <sub>10</sub> B <sub>5</sub> | 3,390                     | 4,770 |
|                          | State recommendation   | 2,000                     | 2,800 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>0</sub> Zn <sub>20</sub> Mn <sub>10</sub> B <sub>5</sub>  | 2,800                     | 3,930 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>0</sub> Mn <sub>10</sub> B <sub>5</sub>  | 2,900                     | 4,100 |
|                          | N <sub>30</sub> P <sub>90</sub> K <sub>90</sub> S <sub>40</sub> Zn <sub>20</sub> Mn <sub>0</sub> B <sub>5</sub>  | 3,180                     | 4,450 |
|                          | C.D. 5%  | 463                       | 653   |
| C.D.=Critical difference |  |                           |       |

**Table 3.** Loss of profit (US\$) growing rice when state recommendations (SR) and farmer's practice (FP) were compared with soil test-based fertilizer recommendations in eastern India.

| Location | Loss with SR | Loss with FP |
|----------|--------------|--------------|
| 1        | -57.70       | -53.15       |
| 2        | -54.20       | -            |
| 3        | -65.40       | -52.25       |
| 4        | -55.75       | -69.50       |
| 5        | -47.00       | -37.20       |
| Average  | -56.00       | -53.00       |

**Table 4.** Mean values of fertilizer costs and farmer profit comparing soil test (ST) based recommendations with state recommendations (SR) and farmer practice (FP) in five field demonstrations with mustard in eastern India.

|             | Cost of fertilizer, US\$/ha |       |       | Profit, US\$/ha |            |
|-------------|-----------------------------|-------|-------|-----------------|------------|
|             | ST                          | SR    | FP    | ST over SR      | ST over FP |
| Mean values | 83.80                       | 41.70 | 59.00 | 183.00          | 149.10     |

profit by an average US\$360/ha. Many provinces in China, states in India, and other countries of Asia need to revise their fertilizer recommendations based on complete soil testing information.

### Summary

Considering data in this article are derived from research and demonstration trials conducted in temperate to tropical conditions with a wide variety of crops, it should be apparent that soil testing, when done correctly, is key to judicious fertilizer use and maximum economic yield. However, useful results are obtained only when the whole soil testing program operates at a high level of speed, control, and precision while performing a complete analysis.

Testing soil has a cost. However, this should be considered as part of the cost of production of a crop or cropping sequence. If done for the examples used in this article, even using the higher estimate for analysis cost, all results still remain quite profitable for the farmer. Considering one soil test may be useful for two or three seasons...depending on the cropping pattern...the value of the recommendation will increase as the cost of analysis can be spread over several crops. In perennial crops, benefits from proper soil and plant analysis can be realized over several years, making the investment both minimal and wise.

There is also a hidden benefit to soil testing. Following soil test-based recommendations usually improves fertilizer use efficiency, meaning more of the applied fertilizer is taken up by the growing crop to produce higher yields. Higher yields also produce more organic matter to be returned to the soil, while losses of applied N to the environment are reduced, which is important for water and air quality. Considering all its benefits, correct soil testing should be vigorously promoted and utilized throughout the agricultural world. **BC**

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### Reference

Portch, Sam, and Arvel Hunter. 2002. *A Systematic Approach to Soil Fertility Evaluation and Improvement*. PPI/PPIC China Program Special Pub. No. 5.

Note: The publication *A Systematic Approach to Soil Fertility Evaluation and Improvement* is available on request. Contact the PPIC office in Saskatoon, Saskatchewan; telephone (306) 652-3535, fax (306) 664-8941, e-mail: gsulewski@ppi-ppic.org.