Renewable Agriculture and Food Systems: 29(3); 189–191 doi:10.1017/S1742170514000118

Moving beyond the soil test

William Liebhardt*
Former Director, University of California, Davis, Sustainable Agriculture Research and Education Program, Davis, CA USA.
*Corresponding author: wcliebhardt@ucdavis.edu

Accepted 10 February 2014; First published online 2 June 2014 **Commentary**

Good research—whether original, incremental or synthesizing—both satisfies with greater understanding of the world's complexity and suggests new questions. This paper does both. It demonstrates that exchangeable K, the standard for evaluating K in soils, does not predict plant available K and that soil testing alone should not guide farmers in nutrient augmentation—yet another compelling reason to review the efficacy of soil testing in an age when excess agricultural nutrients are a major pollution source and cost producers and consumers. But why, after so many excellent pieces of work, is this still an issue? Without belaboring the points made in this paper, I offer Ireland, a small island, as a case study where long-term systematic research identified this problem, formed a consensus and took action.

After World War II, supplementing soil nutrients with chemical fertilizers increased crop yield throughout the industrialized world. Although yield remains an important goal, environmental concerns over excess soil nutrients as well as the economic cost of fertilizer to farmers and consumers have put diagnostic tools, such as soil testing, under the spotlight.

With all the research that has come out over the past 30 years, we can question K fertilizer recommendations based on what we admit is a flawed system. With the research tools now available, we see soil as a dynamic complex interaction of biological, chemical and physical processes. Current soil testing methods look at the chemical aspect while the plant and soil interact symbiotically and are part of another dynamic system called the environment. It is as though a physician relied upon blood tests alone to determine health. Other indicators reflecting more of the soil/plant K relationship over the growing season are needed.

Consider the plant, integrating all the systems, as the final interpreter of what happens in the field. A 6-inch soil sample is only a snapshot of a small part of the root zone where K is taken up. The plant, during the growing season, is a time-lapse motion picture. Sampling a larger area, plants integrate more information about environmental conditions over time.

Schulte's work confirms the important role of plant analysis in nutrient management[1]. Weaver's work on root development in many plants, including corn, showed corn roots one foot deep with a 2-ft radius 36 days after planting[2]. After 56 days, the roots of a single plant explored about 115 ft^3. and at 115 days roots occupied 200 ft^3.

Olson et al.[3] highlighted another weakness in the soil test tool: how different 'philosophies' affect the soil test data, interpretation and fertilizer recommendations. Field experiments over several years on four major Nebraska soils compared corn yields grown with fertilizer recommendation by five soil testing laboratories operating in that state. Economic and agronomic evaluations of the varied approaches on 29 field comparisons revealed no real yield differences despite wide variation in number, rate and cost of the nutrients.

They conclude, 'Since soil test levels are increasing or at least holding steady with the "nutrient sufficiency" approach to soil testing, we find no economic or agronomic basis for the "balance" or "maintenance" concepts on these representative soils of the Western Corn Belt. Not to be overlooked are environmental implications or the waste of energy and resources from any approach responsible for excessive fertilizer use. It is recognized that reserves of available nutrients in the deep subsoils and underlying soil-forming materials in this region have a substantial bearing on soil test calibration and that different calibrations may exist with less favorable subsoil rooting conditions.'

Although Kahn dealt with K, excess N and P nutrients are also environmental problems in the industrialized world. But if we should improve soil testing and other diagnostic tools, such as plant analysis to determine soil nutrient needs more accurately, could we build consensus between the research community, farm advisors and agricultural producers to implement nutrient reduction while maintaining yield? Ireland, relying upon agriculture and its environment to attract tourists, offers a case study.

Irish soils lack available P, limiting plant and animal production. With the memory of famine, agricultural researchers and farm advisors began promoting chemical fertilizers in the 1950s. Farmers, assisted by a government

© Cambridge University Press 2014

https://doi.org/10.1017/S1742170514000118 Published online by Cambridge University Press

subsidy for P fertilizer, had encouraging yields[4] and in the 1960s–70s chemical fertilizer use increased rapidly. The average soil test P increased tenfold: from less than 1 mg l^{-1} using the Morgan Soil Test in 1950 to over 8 mg l^{-1} by the end of the 1980s due to P fertilizer[5]. Phosphorus fertilizer use stabilized at just over 60,000 t yr^{-1} from the early 1980s to the mid-1990s. Since then the trend has been downwards, mainly due to scientific evidence that excess P inputs contributed to pollution of surface waters[5,6]. According to the Irish Department of Agriculture, chemical fertilizer P use is now under 25,000 t yr^{-1}.

Irish agricultural research at Teagasc played a major role in this transition. A 40-year study (The Cowlands project at Johnstown) measured the effects of P on plant and animal production. Animal live weight gain with zero P treatment was about 66% of treatments receiving P. A Morgan's soil test of 4.1–6.4 mg l^{-1} P gave 90–100% of maximum live weight gain (kg ha^{-1} yr^{-1}) in beef animals. Without P augmentation, the concentration of P in grass was 0.2% and doubled when P was applied[7]. Schulte and Herlihy[8] reported on 32 sites over 4 years showing that fertilizer rates to achieve 95% of potential yield were generally low—at Morgan P in excess of 3 mg l^{-1}. Farmers, encouraged by this increased productivity, thought 'if some is good; more must be better' without realizing 'more' could be harmful.

When the Lee River in Cork, a popular tourist destination, turned green in the late 1980s, the public's eye focused. Irish Environmental Protection Agency (EPA) estimated that about half the phosphorus loss to water is from farming. As a result the National Program for Sustainable Development included the goal of reducing P fertilizer use by 10% per year over 5 years from 1997[9]. In addition, a new phosphate regulation was introduced in 1998 to reduce the P content of fresh water to 0.035 mg P l^{-1} by 2006[9], equivalent to an annual loss of <0.35 kg P ha^{-1}[10,11].

I was involved in analyzing Cowlands data while on sabbatical leave in 1997 and 1998. By that time this research showed excess P as a problem. The Morgan soil test P in the top 0–5 mm portion of soil without P was 5.3 and 51.8 mg l^{-1} for the 30 kg ha^{-1} P treatment[12]. Therefore, the highest concentration of P resides near the top and is most vulnerable to runoff. Tunney[4] demonstrated that farmers were applying much more P than was being removed in crops, animals, milk and water. Furthermore, Ireland was advising more fertilizer P than several other EU countries. Three separate pieces of evidence—crop response, Tunney's balance sheet approach and recommendations used by several other EU countries—all indicated that Irish P recommendations were too high.

Outside the research community there was fierce opposition to these conclusions, particularly from the farm press, fertilizer industry and intensive animal rearing farms (pigs and poultry). Within the scientific community the emphasis shifted from an agronomic issue to an environmental issue. An important step in the process was the International P Workshop (IPW1) organized at Johnstown in September 1995 bringing major world authorities on P together[13]. Then Liam Downey, Teagasc Director, organized a 'Focus on Phosphorus' Conference in 1997 inviting political decision makers to meet with scientists, leading to revisions in the Teagasc P recommendations.

Teagasc and its leadership received abundant criticism for these moves, some from researchers within the organization who had successfully guided earlier P fertilizer work to increase yields. The Department of Environment and EPA may have been influential behind the scenes politically counteracting outside vested interests, while mounting evidence stilled, if not convinced, those within the research community. Political leadership, seeing the threat to precious natural resources, took action. When the EU Nitrates Directive was implemented in Ireland 2006 the Teagasc P recommendations were essentially legally binding.

Teagasc campaigned to change behavior with press, radio and public meetings that offered evidence of the environmental effects of excess P and advised farmers how to bring its use into line with the research. While the farm press and farm organizations continued to criticize, farmers, ever conscious of the bottom line, took this information and acted, almost immediately. P supplements decreased rapidly. In fact, according to Tunney (personal communication) these decreases probably began after the IPW1 meeting. 'No one wanted to be associated with the P campaign up to that point but then everybody wanted to claim that it was their idea and the critics disappeared.' Reducing agricultural P pollution in water is now part of European Union and Irish policy and legislation.

In our own country, we can find examples of efforts by agricultural and environmental science to instruct the community and policy makers to bring about effective change. Wines[14] chronicles phosphorus pollution in Lake Erie, most from agricultural sources and 'the wettest spring on record'. The Maumee River running through Ohio farm country supplies only about 5% of Erie's water but half its phosphorus. Writing in *The New York Times*, he says, 'that summer's algae bloom, mostly poisonous blue-green algae called Microcystis, sprawled nearly 120 miles, from Toledo to past Cleveland. It produced lake-water concentrations of microcystin, a liver toxin, that were 1200 times World Health Organization limits, tainting the drinking water for 2.8 million consumers.'

Like the Lee River, this experience raised public awareness and prompted an urgent call for the 70,000 farmers along the Erie shore to change behavior. Environmentalists raised the cry. Friedman[15] details an Environmental Defense Fund project bringing farmers, scientists and concerned citizens together to address the issue.

https://doi.org/10.1017/S1742170514000118 Published online by Cambridge University Press

'The key question is, how to get enough farmers to practice sustainable agriculture, so that algal blooms and dead zones—whether in Lake Erie or the Gulf of Mexico—become a thing of the past?' she asks. 'The answer lies in convincing farmers that sustainable agriculture is not at odds with high yields and profitability.' In fact, practices such as more efficient use of fertilizer and the creation or maintenance of wetlands and buffer strips, which filter runoff before it can reach streams and rivers, can save farmers money and help improve the quality of their soil.

So let's do this!

References

1 Schulte, E.E. and Kelling, K.A. 1991. NCH-46, Crop Fertilization, April. Cooperative Extension Service, Purdue University, West Lafayette, IN.

2 Weaver, J.E. 1926. Root Development of Field Crops. 1st ed. McGraw-Hill, New York.

3 Olson, R.A., Frank, K.D., Grabouski, P.H., and Rehm, G.W. 1982. Economic and agronomic impacts of varied philosophies of soil testing. Agronomy Journal 74:492–499.

4 Tunney, H. 1990. A note on a balance sheet approach to estimating phosphorus fertiliser needs of agriculture. Irish Journal of Agriculture Research 29:149–154.

5 Tunney, H. 2002. Phosphorus needs of grassland soils and loss to water. In J. Steenvoorden, F. Claessen, and J. Willems (eds). Agricultural Effects on Ground and Surface Waters: Research at the Edge of Science and Society. International Association of Hydrological Sciences, Wallingford, UK. p. 63–69.

6 Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E. 1997. Phosphorus Loss from Soil to Water. CAB International, Wallingford, UK.

7 Tunney, H., Kirwan, L., Fu, W., Culleton, N., and Black, A.D. 2010. Long-term phosphorus grassland experiment for beef production—impacts on soil phosphorus levels and live weight gains. Soil Use and Management 26:237–244.

8 Schulte, R.P. and Herlihy, M. 2007. Quantifying responses to phosphorus in Irish grasslands: Interactions of soil and fertiliser with yield and P concentration. European Journal of Agronomy 26:144–153.

9 Anon, 1997. Sustainable Development—A Strategy for Ireland. Government Publications Office, Dublin.

10 Anon, 1998. Water Quality Standards for Phosphorus-Regulation 1998 (under the 1977 Water Pollution Act). Government Publications Office, Dublin.

11 Tunney, H., Foy, R.H., and Carton, O.T. 1998. Phosphorus inputs to water from diffuse agricultural sources. In J.G. Wilson (ed.). Eutrophication in Irish Waters. Royal Irish Academy, Dublin. p. 25–39.

12 Culleton, N., Coulter, B., and Liebhardt, W.C. 2002. The fate of phosphatic fertilizer applid to grassland. Irish Geography 35:175–184.

13 Tunney, H., Breeuwsma, A., Withers, P., and Ehlert, P. 1997. Phosphorus fertiliser strategies, present and future. In H. Tunney, P.C. Brookes, O.T. Carton, and A.E. Johnston (eds). Phosphorus Loss from Soil to Water. CAB International, Wallingford, Oxfordshire, UK, p. 117–203.

14 Wines, M. 2013. Spring rain, then foul algae in ailing Lake Erie. The New York Times, March 14.

15 Friedman, S. 2013. Lake Erie is sick. Can farmers and businesses cure it? Ecosystems, May 17.

https://doi.org/10.1017/S1742170514000118 Published online by Cambridge University Press