Soil C levels The effect of mineralizing N is to reduce C so that soil C levels have declined. With the current interest in C sequestration, LTAEs such as LR1 can provide unique real world data on soil C stocks under different farming systems. In 1916, when the experiment was established, such a ques-tion would not have been thought of and now as part of a new research project, this site will be used to measure soil C stocks to depth and accounting for soil bulk density.

Conclusion

At the most fundamental level, LTAEs provide us with reassurance that cropping and pasture systems can operate for many decades and depending on the strategies adopted, continue to produce food and fibre with resource protection. While cropping and pasture systems computer simulation models can help refine information, they do require real world data to calibrate against. Conclusions based on 10 to 20 years of experimental data can be quite different to those based on 50 years of data. Long-term agronomic experiments have pro-vided us with understanding about the trends in productivity associated with different crop sequences and tillage operations. Since their inception, we now use LTAE's to help identify fac-tors affecting sustainability and environmental quality as well as species impacts in response to change.

While we know a lot about the effect of systems on soil health ("knowns"), there are things we have not yet param-eterised ("known unknowns", such as soil C). There are other things we have not even considered. Dealing with "unknown unknowns" is difficult to cost and plan for, but having well planned and suitably resourced long-term experiments can play a vital role in such studies. As Rassmussen et al. (1998) indicated, "We need continuity with the past to better predict the future."

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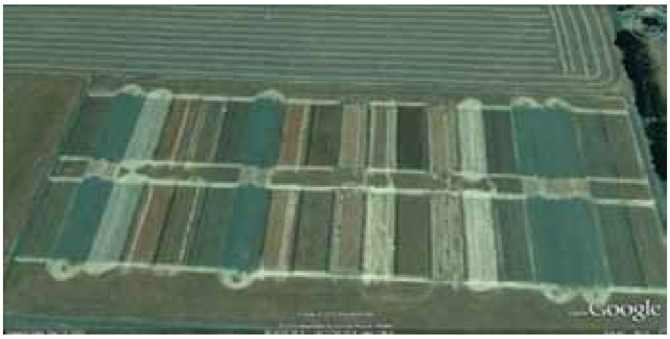

Google Earth/DigitalGlobe view of LR1 showing the plot layout. All plots were originally one acre each. In 1986, they were split, with the southern half using the latest cultivars while the northern half retained the traditional variety Ghurkha wheat.

Acknowledgments

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The Essential Role of Soil Organic Matter in Crop Production and the Efficient use of Nitrogen and Phosphorus

By Johnny Johnston

The role of soil organic matter (SOM) in supporting the nutrient requirements of high crop yields is fundamental, especially as crop yield potential continues to improve. Lessons on N and P interactions with SOM and its support of high crop yields are well illustrated here through examples gleaned from long-term research conducted at Rothamsted.

A first example of the contribution of SOM towards en-hancing crop productivity is provided here through use of data from the Hoosf eld Continuous Barley experi-ment at Rothamsted. Started in 1852 on a silty clay loam soil, the Hoosf eld site received annual application of NPK fertil-izers, or farmyard manure (FYM) at 35 t/ha, which produced soils that now have 1.74 and 6.16% SOM, respectively. Each year since 1968, four amounts of fertilizer N (0, 48, 96, and 144 kg N/ha) are applied to these soils. Beginning in the mid 1970s, **Figure 1** plots changes in grain yield of three succes-sive cultivars of spring barley, each with higher yield potential than its predecessor. On the soil with lower SOM, the crop responds to N and there is little difference in maximum yield of the three cultivars in the three periods. On soil with more SOM, the crop responds only a little to fertilizer N, but as the yield potential of the crop has increased, the maximum yield on this soil has increased—as has the benef t from having more SOM. The difference in maximum grain yield on the two soils is now more than 2.5 t/ha.

Similarly, on the Broadbalk winter wheat experiment, soils treated with fertilizers or FYM (35 t/ha each year) since 1843 now contain 1.93 and 4.87% SOM, respectively. Different amounts of N have always been tested with PK fertilizers and the resulting yields have compared with those given by FYM alone. In many years before 1967, grain yields with FYM were slightly better than with fertilizers (Garner and Dyke, 1969), but the yield increase due to FYM for winter wheat was not as large as that with spring barley, probably because winter wheat has a longer growing season in which to make a root system. Since 1968, when short-strawed cultivars were intro-duced with improved grain-to-straw ratios and higher yield potentials, yields have only been larger on FYM-treated soil if an additional 96 kg N/ha is given as fertilizer. Interestingly, when cv. Hereward began to be grown at Broadbalk in 1996, the addition of 96 kg N/ha with FYM no longer gave a larger yield than the optimum NPK fertilizer application (Johnston et al., 2009). Since 2005 it has been necessary to add 144 kg N/ha with FYM to give slightly larger yields than with fertilizers. It would seem that the available N from 35 t/ha FYM, and that mineralized from the accumulated SOM, is not suff cient to give maximum yields of a cultivar of winter wheat with a large yield potential. It would be interesting to speculate why this is so.

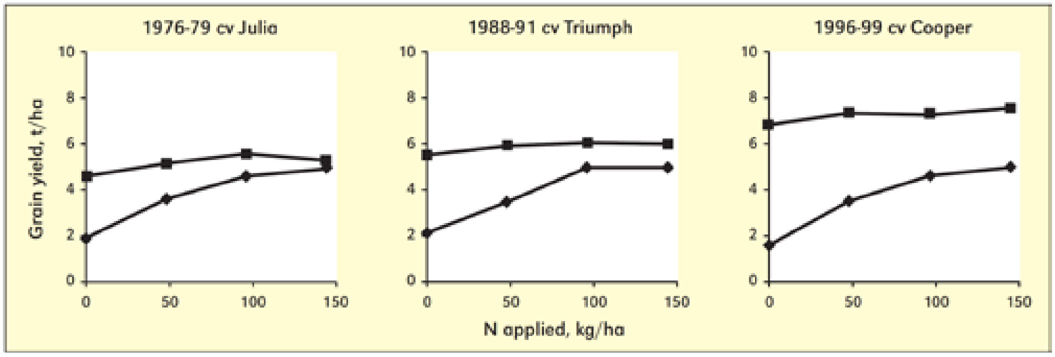

Figure 1. O Grain yield response to applied N from three spring barley cultivars with increasing yield potential (left to right) grown on two soils with 1.74◆) or 6.16 ■ % SOM, Hoosfield Continuous Barley experiment, Rothamsted.

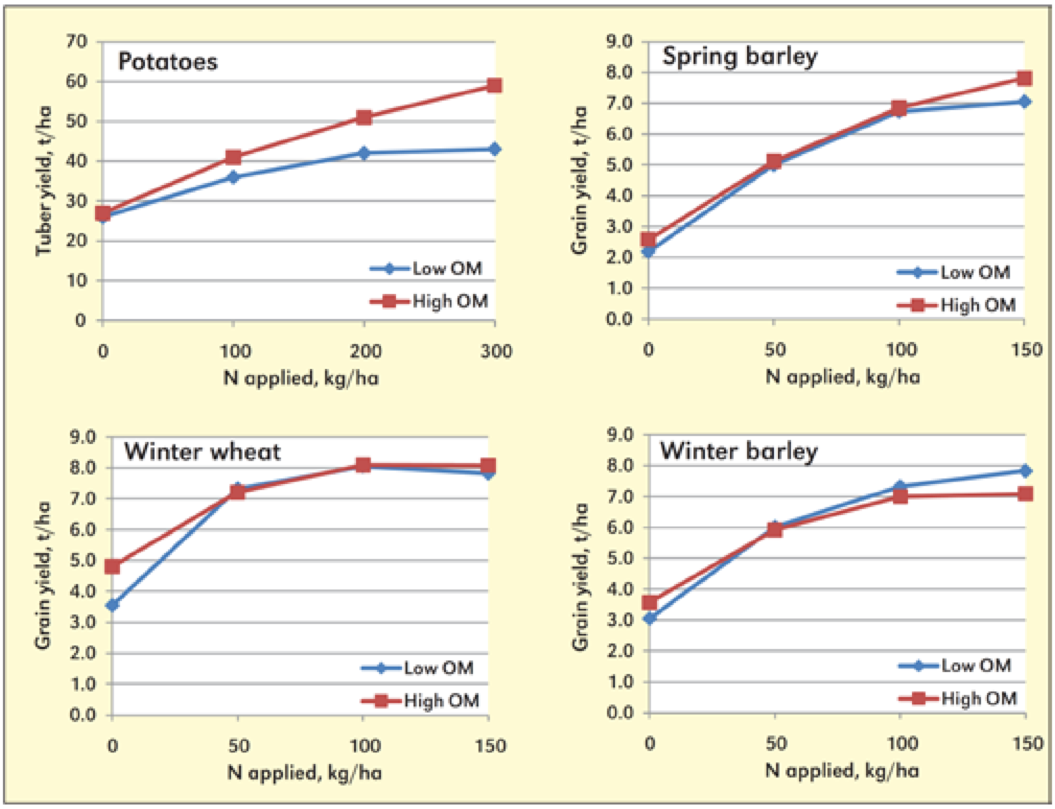

Figure 2. Yield response to applied N by spring and winter crops grown on a sandy loam soil with two levels of SOM, 1.3 and 3.4%, respectively.

Soil Organic Matter and Nitrogen Interactions

At the present time there is considerable interest in the ef-f cient use of N in agriculture. This arises not only because the different forms and pathways by which N can be lost from soil can have adverse environmental impact, but also because such losses are a direct cost to growers. There is much evidence to show that N is used more eff ciently on soils with more organic matter, and presumably a better structure, so that roots explore the soil more effectively to f nd nutrients.

On a sandy loam soil with two levels of SOM, potatoes, spring barley, winter wheat, and winter barley have been grown in different years, each crop given four appropriate amounts of N (**Figure 2**).

Yields of the spring sown crops, potatoes and barley, were always larger on the soil with more SOM irrespective of the amount of N applied, and the recovery of the applied N was greater where the yields were larger. A better soil structure with more SOM allowed for quicker root development and bet-ter exploration of the soil mass for nutrients. At each amount of applied N, the yields of the winter sown cereals, with a longer growing period than a spring-sown crop, were largely independent of

SOM, probably because these autumn-sown crops had time to develop an adequate root system on the soil with less SOM.

In another experiment on a sandy loam soil, the effects of various organic amendments on SOM and yields of arable crops have been tested since 1964 with two periods of organic additions (the “treatment” period) and two periods of arable “test” cropping (Johnston et al., 2009). Annual organic treat-ments that were common to both periods of addition included incorporating straw (7.5 t/ha dry matter), applying FYM (50 t/ha fresh material) and growing and then incorporating a grass/clover ley (temporary pasture) before growing arable “test” crops to measure the effects of any additional SOM built up during the two “treatment” periods.

In 1986, C in the top 23 cm was 0.65% without organic addition—about the equilibrium level for this soil and treat-ment. The organic additions increased it to 0.85% with added straw, 1.06% with FYM, and 0.90% following the incorporation of an 8-year grass/clover ley. The yields of potatoes (in 1988 and 1989) and winter wheat (in 1987 and 1988), each testing six amounts of N, are compared with those on soils without extra organic matter addition in **Figure 3**. Yields were always smallest on soil with least SOM and generally largest on soils ploughed out from the grass/clover ley. In all comparisons, less N was needed to achieve optimum yield on soil with more SOM.

There are two interesting features in these results. First, in **Figure 3a**, the largest winter wheat response to the maximum amount of N tested was on the FYM treatment—an effect similar to that on the Broadbalk experiment discussed earlier, and perhaps explained for the same reason. Second, following the ploughed-in grass/clover ley, the largest yields were with the second increment of N tested, suggesting that there could have been some benef cial effect late in the growing season from N mineralized from the N-rich ley residues ploughed-in the previous autumn. If this mineralized N is lower down in the soil prof le, where roots are actively taking up nutrients, then such a benef cial effect would be diff cult to mimic with fertilizer N applied on the soil surface.

Two further comments about these results; first, although best yields followed the grass/clover ley, having a ley for 3 years must be economically vi-able within the whole farm budget. Second, there was continued benef cial effects from straw incor-poration, one of the few methods available to many farmers for slightly increasing or maintaining SOM, and perhaps preventing SOM decline.

Soil Organic Matter and Phosphorus Interactions

In addition to important interactions between SOM and the response to N, there are equally important interactions between SOM and plant-available P in soil. In an experiment on a silty clay loam soil, known to be diff cult to cultivate, especially in spring, plots were established over a 12-year period with two levels of SOM, 1.5% (the arable plots) and 2.4% (the grass plots), and 24 levels of Olsen-P at each level of SOM. After the 12-year preparatory period, potatoes, sugar beet, and spring barley were each grown twice in rotation in 3 years. The

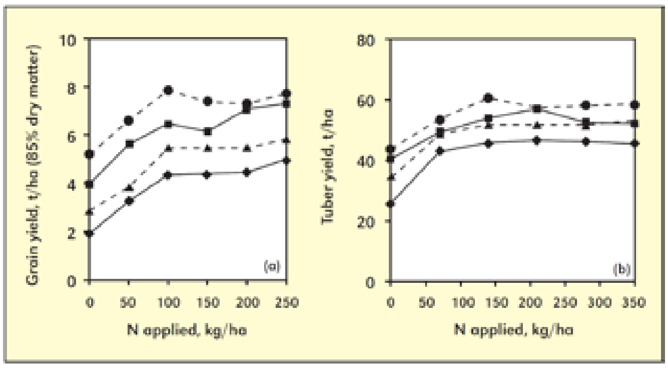

Figure 3. Yield response to N rate for winter wheat in 1987/88 (a) and potatoes in 1988/89 (b) after periods of various organic treatments (see text). Treatment and % SOM: No organic amendment, 0.65% SOM ( ); incorporating straw, 0.85% SOM ( ); adding FYM, 1.06% SOM ( ); incorporating a grass/clover ley, 0.90% SOM ( ).

2-year average yield of each crop was plotted against Olsen-P, and the response curve f tted statistically to determine maximum yield and Olsen-P associated with 95% of the maximum yield (**Table 1**).

The 95% yield of spring barley was appreciably smaller on soil with low SOM compared to that on soil with high SOM, but potatoes and sugar beet gave similar yields on both soils because better seedbeds could be prepared for these two crops sown later than spring barley. Of great importance, however, the level of Olsen-P associated with the 95% yield was much lower on soil with more SOM. The effect of SOM was to improve soil structure so that roots could grow more freely and explore the soil more thoroughly to f nd plant-available P.

Subsequently, soil samples from all 48 plots (two levels of SOM x 24 levels Olsen-P) were cropped with ryegrass under uniform conditions in the glasshouse. The cumulative yields from four harvests were plotted against Olsen-P and the response curves on soil with the two levels of SOM were not visually different. The 95% yields were virtu-ally the same as were the Olsen-P levels associated with these yields (Table 1) strongly suggesting that soil structure in the f eld was the explanation for the large differences in Olsen-P associated with the 95% yields.

Table 1. Crop yield and Olsen-P associated with 95% of the maximum yield determined by plotting the 2-year average crop yields against Olsen-P.

Crop yield	Soil organic matter, %	Yield at 95% maximum, t/ha	Olsen-P associated with 95% yield,mg/kg	R^2
Field experiment				
Spring barley grain, t/ha	2.4	5.00	16	8.83
	1.5	4.45	45	0.46
Potatoes tubers, t/ha	2.4	44.7	17	0.89
	1.5	44.1	61	0.72
Sugar beet sugar, t/ha	2.4	6.58	18	0.87
	1.5	6.56	32	0.61
Pot experiment				
Grass dry matter, g/pot	2.4	6.46	23	0.96
	1.5	6.51	25	0.82

Summary

It is not easy to increase SOM in many arable cropping systems unless it is possible to add large amounts of organic materials. However, every attempt should be made to conserve and increase SOM wherever possible because it improves soil structure and thus the ability of plant roots to grow through the soil to f nd the nutrients required to optimize growth and yield. This is especially so in relation to the acquisition of N and P and thus their eff cient use in agriculture.

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Improvement of Diagnosis Accuracy of Phosphate Status for Ukrainian Soils

By Anatoly Khristenko and Svetlana Ivanova

Through an analysis of the effect of soil properties on the accuracy of the Olsen P soil test, a refined method and interpretive scale for available soil P supply was developed for use in alkaline soils.

Studies performed at the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky, National Academy of Agrarian Science, Ukraine, show that some chemical methods used for the determination of plant available elements involve large errors. In particular, the error for determining available soil P or K based on former Soviet Union soil testing standards can reach 100 to 200% or more. Most methods include the use of strong acid solutions that can underestimate results for all coarse (sandy and loamy sandy) soils, as well as for strongly acid (pH_{KCl} < 4.5) soils of different textures, and can overestimate results for soils with high contents of primary P-containing apatite minerals.

Presently eight national soil test standards and five standard drafts have been developed for Ukraine's 32 million ha of arable land. The process began with the identification of Ukrainian regions and soil types for which specific chemical methods of determining plant available N, P, and K are most advisable. The potential effects of soil composition and physical properties on the results of chemical analyses were taken into consideration. New scales of soil supply for available P or exchangeable K were developed for some methods that together specify methods for determining plant available N, P, and K for all soils of the country.

The use of State standards, including the Olsen, Machigin, Chirikov, Kirsanov, and Karpinskii–Zamyatina methods (described below), has generally meant that available P status of arable soils under extensive agricultural use fall within the low-to-medium supply levels, while available K status is generally considered medium. This agrees with well-known empirical data that demonstrates high efficiency of mineral fertilizers, especially P fertilizers, on all types of arable soils of Ukraine, including its chernozems. New regulatory soil tests explained below, demonstrate an increase in accuracy of the diagnosis of soil fertility. The subsequent correction of fertilizer application rates, and more rational distribution of fertilizers among fields and crops, can increase use efficiency by an average of 30%.

Errors in soil testing theory and methodology create overestimation (or underestimation) of results for not only individual fields, but also entire regions. An illusion of rich chernozems on loessial rocks is related to the increased content of P-bearing apatites and K-bearing feldspars in these soils. However, P or K present in these minerals are not directly available to plants. At the same

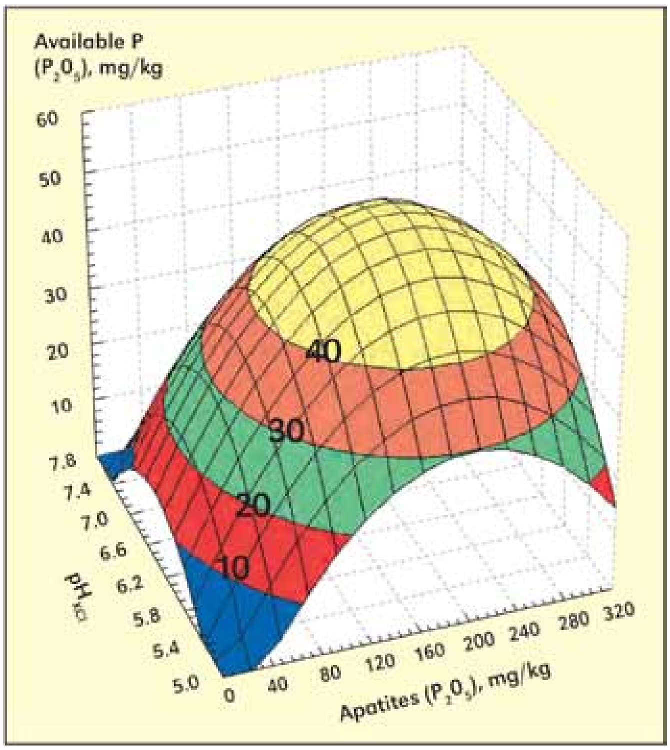

Figure 1. Determination of P in 21 soil samples representing common soil types of Ukraine and Russia by the Egner–Riehm method depending on soil pH and apatite content (Ca–P fraction).