FORUM: Agriculture

Comparing apples with oranges

A meta-analysis of agricultural systems shows that organic yields are mostly lower than those from conventional farming, but that organic crops perform well in some contexts. Agricultural scientists discuss whether the conclusions of the study should change farming practices and management. SEE LETTER P.229

THE PAPER IN BRIEF

- A growing human population poses challenges to agricultural sustainability and food security.
- Organic farming is deemed less environmentally damaging than non-organic systems, but it may require more land to produce the same amount of food.
- Seufert *et al.*[1] (page 229) did a categorized analysis of existing data to compare the efficiency of the two agricultural approaches.
- The authors find that, although organic yields are lower on average, they are almost equivalent to conventional yields for some crop types and when good organic management practices are used.

The fruits of organic farming

JOHN P. REGANOLD

Yield differences between organic and conventional farming systems are a topic of intensive debate, and numerous studies have compared crop yields. Yet few studies have synthesized this information on a global scale. In a meta-analysis, Seufert *et al.*[1] show, from 316 yield comparisons in 66 studies, that organic farming systems in developed countries produce yields that are 20% lower than their conventional counterparts. This discrepancy rises to 25% when data from developed and developing countries are combined. However, the authors also found that for certain crops (Fig. 1), growing conditions and management practices, organic yields nearly match those from conventional systems. These findings underscore the potential for organic farming to have an increasing role in a sustainable food supply.

In the first extensive review of organic versus conventional yield data, conducted in 1990, Stanhill[2] found organic yields to be 9% lower than conventional yields in developed countries. A subsequent study by Badgley *et al.*[3] found this difference to be 8%. In another recent meta-analysis of 362 yield comparisons, de Ponti and colleagues[4] found organic yields to be 21% lower in developed countries and 20% lower globally. In addition, they found that the best-yielding organically grown crops are rice (6% lower yield than conventional), soya beans (8% lower), corn (11% lower) and grass–clover (11% lower). In comparison, the highest-yielding organic crops identified by Seufert and colleagues were organic fruits (3% lower yield than conventional), rain-fed legumes such as soya beans (5% lower) and oilseed crops (11% lower).

One likely reason for greater average-yield differences in the Seufert *et al.*[1] and de Ponti *et al.*[4] meta-analyses, compared with the earlier studies[2,3], is their more restrictive selection criteria. For example, Seufert and colleagues excluded 268 possible yield comparisons simply because the studies failed to report sample size or estimates of standard error. As the authors admit, their criteria also biased the analysis of yields in developing countries by using atypically higher conventional yields — in 58 of their 67 comparisons in this category, conventional yields were more than 50% higher than average yields from the respective regions.

Nevertheless, Seufert and colleagues reveal remarkable findings when the systems are further stratified according to different categories, such as crop type, level of management and the stage of crop growth — an example of meta-analysis being a great tool for identifying broad patterns not immediately visible in primary field research[5]. Although this analysis technique must also be treated with caution (because no single farming system or practice works best in every location), both the Seufert *et al.* and de Ponti *et al.* studies bolster the argument that adoption of organic agriculture under conditions in which it performs best might close the yield gap between organic and conventional systems.

If we want to feed a growing world population, producing adequate crop yields is vital. But, as described in a report[6] by the US National Research Council (NRC), sufficient productivity is only one of four main goals that must be met for agriculture to be sustainable. The other three are enhancing the natural-resource base and environment, making farming financially viable, and contributing to the well-being of farmers and their communities. Conventional farming systems have provided increasing supplies of food and other products, but often at the expense of the other three sustainability goals. The NRC report[6] identifies organic methods as one of several innovative systems that better integrate production, environmental and socio-economic objectives. Other such systems include agroforestry, hybrid organic–conventional agriculture, conservation agriculture, grass-fed livestock production and mixed crop–livestock systems.

No one of these systems alone will produce enough food to feed the planet. Rather, a blend of farming approaches is needed for future global food and ecosystem security. Organic farming provides multiple sustainability benefits, and Seufert and colleagues' findings indicate that it can play a part in feeding the world. Yet just under 1% of agricultural land worldwide is now managed organically[7]. This percentage should be much larger in the future.

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Getting back to the field

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Seufert and colleagues[1] have added another meta-analysis to the popular debate on whether organic agriculture systems can feed the world, which joins a similar recent analysis by de Ponti *et al.*[4]. Both studies report similar results: that yields of well-managed organically grown crops average about 75–80% of the crop yield under conventional management, and that

L. VEIGA/GETTY IMAGES

Figure 1 | Crunch time for agriculture. Seufert and colleagues' meta-analysis[1] shows that for some organic crops, such as apples, farming yields almost match those from conventional agriculture.

the size of the yield gap is highly contextual. The more rigorous selection criteria and analysis methods used in these two studies make them a substantial improvement on previous studies that suggested only slightly lower organic yields or yields that even exceeded those obtained with conventional farming. The analysis methods used to derive such estimates, particularly those used by Badgley *et al.*[3], were, in my and others' opinion[8], questionable, owing to their reliance on yield ratios that in many cases represented large differences in crop management, particularly in nutrient inputs.

Despite the valuable contribution of the two new studies, the results are hardly surprising. Any experienced agronomist or farmer knows that achieving a high crop yield requires a well-adapted plant variety, sufficient sunshine, water and nutrients, and good soil and crop care. These prerequisites do not differ between conventional and organic agriculture.

It is time to accept that various types of agriculture can have a place in feeding the world, depending on the availability of land, the degree of self-reliance of agricultural systems in terms of critical inputs to value chains (such as nutrients and other resources), the scale of food production, and the desired and feasible trade in agricultural goods[9]. But we also need to leave vague, outdated concepts of sustainability behind, because the real picture is much more complex than it seems. Organic or low-external-input agriculture is not always sustainable[10]. There are also many conventional agricultural systems that are highly productive, resource-efficient and sustainable[11] — and some have been so for a long time. Instead of doing further meta-analyses to attempt to determine the optimal combination of agricultural systems, scientists should return to their fields and laboratories, and concentrate their efforts on increasing the performance of both conventional and organic agriculture.

What should scientists study? As de Ponti *et al.* point out, one issue is the scaling-up of organic agriculture. Side-by-side comparisons at the field or plot scale have shown that ensuring a sustainable, cost-effective supply of plant nutrients is a key constraint in organic systems, irrespective of whether the materials providing the nutrients are organic or mineral. Therein lies the biggest challenge for larger-scale organic agriculture. The most relevant parameter for food security and for preserving natural ecosystems is food output per unit area-time — which should ideally be optimized on existing agricultural land. But land, time, labour, money and transport are required to produce and distribute nutrients from organic sources. Where would the extra land to grow the extra nutrients be found? Comparative studies are needed to assess what scale of organic agriculture might be feasible from a nutrient capture and transfer point of view, and where this could be done.

We also need more evidence that organic agriculture systems can be designed so that they do not require premium prices or government subsidies to remain economically viable. If that cannot be shown, how will we progress in the fight to combat poverty, hunger and malnutrition in developing nations?

Yield and input-efficiency gaps exist in both organic and conventional agriculture. Closing these gaps and meeting high profitability, environmental, sustainability and social standards are not mutually exclusive goals, but the value chain (from seed to table) that should be implemented will depend on local conditions. Fine-tuning these requirements requires a more accurate understanding of crop yield potential, yield gaps, resource efficiencies, environmental impact and sustainability in quantitative terms than we have currently — to provide us with the precise agricultural technologies needed to reach higher performance and sustainability standards. Comparing one system with another in relative terms will not enhance our understanding of the requirements for a better yield, but well-designed experimental research at scales relevant to the production level may. ■

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MATERIALS SCIENCE

Cracks tamed

Crack propagation in materials is rarely welcome. But carefully engineered cracks produced during the deposition of a film on silicon can be used to efficiently create pre-designed patterns of nanometre-scale channels. SEE LETTER P.221

ANTONIO J. PONS

The potential mechanical energy stored at the interface between a film and an underlying crystal substrate[1] can, in some cases, be released in the form of a crack that propagates through the laminate material (Fig. 1). Fissures produced in this way usually spread freely. But on page 221 of this issue, Nam *et al.*[2] present a technique that fully controls such fracture progression. As a result, the authors were able to fabricate microscopic patterns of cracks, thereby unveiling a promising alternative to other high-resolution approaches to making patterns of channels on surfaces for applications in fields such as