Opinion

Cell PRESS

The cult of the amateur in agriculture threatens food security

Anthony Trewavas

Institute of Molecular Plant Science, University of Edinburgh, Mayfield Road, Edinburgh EH9 3JH, Scotland

The incorporation of science and technology into agriculture has led to enormous growth in crop yields, providing food security in many countries. From the 1950s onwards there has been increasing interference in agricultural policy by a few scientists who are marginal to agriculture and from a variety of unqualified groups. These groups and individuals have used fear and anxiety and have greatly exaggerated minor problems to persuade an unqualified public of supposed dangers in food and to try and change agricultural policy. Fear and emotion do not lead to good policy, and the cult of the amateur that has developed could have serious repercussions on vital food security and future agriculture in developing countries; it must be soundly rejected.

Background

The commodity price of wheat (and other cereals) has recently doubled, and it is now threefold higher than 2002 (http://www.oecd.org/document/29/0,3343,fr_2649_201185_40717917_1_1_1_1,00.html). There have been demonstrations, riots and deaths in the poorest countries, and the World Bank estimates that 33 countries face potentially damaging social unrest. During the past 50 years, a relative abundance of food saw its global price drop by half, with the poorest benefitting most. But this current price increase is probably permanent and likely to get worse. The global food market, always riddled with subsidy and tariffs, is now experiencing export bans from some producers. Since 75% of UN countries are net importers of food, food security for the majority is suddenly at risk. Meanwhile, in Europe, politicians obstruct the implementation of research and listen instead to unqualified environmentalists. The spectre of widespread famine, starvation and, at the least, serious malnutrition has returned again to haunt mankind.

Conventional agriculture is successful and sustainable

Current conventional agriculture can support ~1000 people/km^2; a 1000-fold higher than hunter gathering [1]. As populations grew enormously in the last century, the input of knowledge, science and technology enabled agriculture to cope, providing (until last year) relatively cheap, abundant food to over 80% of its people. In western countries, yields/ha have more than doubled in the past 50 years. Developing countries also benefitted from the high-yielding green revolution cereals, which are estimated to have saved one billion from direct starvation [2]. Since there is little cultivable soil left worldwide, feeding an additional 2.5 billion people – the increase in population expected by 2050 – will require an increase in yields/ha of two- to threefold [2] because richer populations increase their meat consumption and cattle are fed grain.

Conventional agriculture is perfectly sustainable when properly conducted, as the 165-year-long Broadbalk experiment (Rothamsted, UK) demonstrates (Rothamsted Research, http://www.iacr.bbsrc.ac.uk/res/corporate/ltexperiments/tbwinterwheat.html). Improved farming procedures include the holistic Integrated Farm Management (http://www.leafuk.org) and no-till farming (conservation tillage) [3]. The latter farming method eschews the plough, using herbicides to control weeds. Measurements have shown greenhouse gas emissions from no-till farms are one-third those of organic farms because ploughing is fossil-fuel intensive. Furthermore, increased oxygen penetration of the soil greatly accelerates microbial oxidation of soil carbon. But no-till greatly increases biodiversity and soil erosion is eliminated [4,5].

The most recent agricultural tool is the use of recombinant DNA technology [genetic modification (GM)], which can speed up the production of new varieties. Transforming crops with a gene for herbicide resistance has seen enormous uptake of no-till agriculture in the USA, where 10% of farms are totally no-till and another 60% are partially no-till. Furthermore, transformation of crops with an insecticidal protein that is selective for certain moth larvae (Bt) has been accompanied by huge reductions in chemical pesticide use and has led to the recovery of natural pest predators. Many other GM crops are in the pipeline or are already in use, including those conferring drought and virus resistance, improved nutritional value, vaccine production, and others [6].

Opposition to agricultural knowledge

The publication of 'Silent Spring', a misleading polemic about pesticides (specifically DDT) by Rachel Carson saw the start of opposition to conventional agriculture [7]. Her knowledge of toxicology, which was the real subject of her book, was poor; unsurprising because she was actually a marine biologist. However, her message of fear, despite her marginal qualification, appealed to a section of the public, who were even less qualified but strongly opinionated. As a result of minority agitation, bans were imposed on DDT use. The disastrous consequence was an enormous resurgence of malaria in developing and third world countries where it had been virtually eliminated and the associated premature deaths of many millions of third world children

Corresponding author: Trewavas, A. (trewavas@ed.ac.uk).

0167-7799/$ – see front matter doi:10.1016/j.tibtech.2008.06.002

[8]. That is the true Carson memorial. The western environmental activists whose thoughtless agitation was responsible for implementation of the ban have never shown sorrow or contrition. Moderation of DDT use would have been a more sensible course of action.

DDT is an organo-halogen and remarkably non-toxic to mankind but supposedly banned because of its bioaccumulation. There are at least 3800 organo-halogens made naturally by marine organisms: some even have chemical structures similar to currently used fire retardants [9,10]. Some of these natural organo-halogens bioaccumulate through marine food chains and have even been detected in human breast milk. What next, ban nature?

Mankind values what is scarce. An abundance of cheap, nutritious food from the late 1960s onwards produced government and public indifference. Governments had decided food security was solved and need no longer be their concern. Consequently, agricultural research funding was slashed, institutes were closed and related university courses abandoned. Technological advances were no longer defended against environmental agitation. It was quickly forgotten that the prime aim of agriculture was to grow food and provide food security. Various environmental groups moved to fill the vacuum left by government and to get their way, trafficked in fear. There had always been envy amongst these environmentalist groups of the status accorded to scientific knowledge, and the aim was to replace it with policies based on their own fears and ignorance. To promote organic agriculture, for example, it was claimed that synthetic pesticide traces ('chemicals') were dangerous, citing biological effects observed in test animals at amounts ~1 million times higher than present in foodstuffs.

Those who agitate about pesticides can list the names of the pesticide traces in their food down to the femto-mole level. But the name of any natural pesticide escapes them. Higher plants synthesize an estimated 100 000 natural pesticides (representing 1–5% of the dry weight) that efficiently kill insect herbivores [11–13] and occasionally humans [14]. Many of these have been extracted, and when tested like synthetic pesticides are equally toxic. The average fruit and vegetable diet contains numerous nerve toxins, carcinogens, teratogens, oestrogen mimics, clastogens, psychoactive chemicals and other chemicals that damage blood, thyroid and skin; similar if not identical in action to the biological effects of synthetic pesticides. But at 2–3 gm/day in the average diet, these natural chemicals outweigh the synthetic traces by at least 20 000-fold. Environmentalist groups claim there are possible health effects of a 'cocktail' of synthetic pesticides. But since each crop species synthesizes its own unique natural pesticide mixture, the natural risk is many orders of magnitude higher. Public and activist concern is like worrying about a cold when ebola is rife.

The political response to agitation was to construct regulations, but this only heightened concern where it didn't exist before; food must contain something dangerous now it had to be regulated. What was needed instead was leadership to assert the primacy of knowledge over opinionated ignorance.

All farming methods have costs and benefits, and decisions are based on the perceived balance between these. But assessment can never be absolute: the context is crucial. When food is scarce, organic agriculture, with its diminished yields, declining soil fertility, rigidity of regulation and high priced produce, is not appropriate. The agriculture needed for the future must show flexibility, a potential to increase yields substantially worldwide and the ability to provide good income for the farmer. Only scientific knowledge and research can do that.

With the advent of recombinant DNA technology (GM), organic associations, never too clear on how the crops they used were produced, opposed the technology. The most likely reason was that GM crops would act as real competitors in reducing pesticide use, thus removing a justification for organic products in the first place. Early attempts to improve crop pest resistance used random mutagenesis to create novel pest-resistance genes [15]. Several thousands of such treatments of crops have been recorded by the International Atomic Energy Commission, and the mutated genes are found in most of the varieties currently used, including those inevitably popular with organic farmers. Thus, the environmentalist stance that slavishly followed the decision of organic associations could hardly claim that using mutated plants was dangerous. Instead, an uninformed public was bombarded with claims that GM food was unsafe and it was the technology itself that was at fault. These environmentalist claims found support from a very small number of scientists who, although completely marginal to and inexperienced in GM technology, safety and risk assessment, plant breeding and toxicology, decided to test GM crops themselves. When scientists venture into areas in which they have no experience, foolish mistakes are easily made, as they were in these cases (e.g. the Pusztai case [16] or the Ermakova case [17]).

Two excellent recent papers, amongst others, have indeed established that GM technology is less perturbing than current plant breeding methods. In the first study, hierarchical metabolomics has been used to compare the detailed composition of several GM potato lines and equivalent untransformed varieties. GM technology convincingly perturbs the metabolism to a less extent than conventional variety breeding [18]. The second paper used a detailed microarray analysis that compared GM, mutagenized and untransformed equivalents in rice. Genomic alterations were much more extensive in the mutagenized lines, that is, in plants considered safe and without any effects on human health and that are of course used by organic farmers [15]. A compilation of the numerous peer-reviewed papers that have investigated and subsequently established GM food safety is available*.

The cult of the amateur

The Cult of the Amateur, a book authored by Keen [19], is particularly applicable to agriculture. His concern is the blurring of the distinction between the qualified and informed professional and the uninformed and unqualified amateur that results from instant internet access. He

* Chassy, B.M. *et al.* (2005) Crop biotechnology and the future of food: a scientific assessment. CAST Commentary QTA 2005-2 (http://www.biotech.ucdavis.edu/PDFs/MCB294%20GMOs%20fictions,%20Facts%202-3-06.pdf).

correctly observed that: 'We are facing the law of digital darwinism, the survival of the loudest and most opinionated' and 'In a world where everyone has a say, the words of a wise man count for no more than the mutterings of a fool' [19]. He states that societies create structures of authority that aim to provide reliable expert knowledge to a public otherwise unable to discriminate between the foolish, the fundamentalist, the vociferous or the wise.

Is it wise to obtain reliable information on open heart surgery from a local butcher or from a skilled heart surgeon? Is it wise to ask a bus driver how to fly a jumbo jet or instead ask a long-experienced jumbo jet pilot? Or should we ask someone whose experience of shipping is limited to rowing a boat how to captain a supertanker? Although 70% of air crashes are due to pilot error, medical mistakes are not uncommon and occasionally even supertankers sink, amateur involvement would guarantee almost certain immediate disaster. But in agriculture, pesticides, food and farming, expert scientific knowledge and experience is seemingly regarded as having no more weight than that of the opinionated, unqualified (and inexperienced) environmentalist. If scientific knowledge is not the foundation of policy, then ignorance will directly lead the way to starvation, as indeed has already begun to happen. People are entitled to their opinions, but unless they are based on extensive qualification and experience, they are of little or no value for policy.

A typical example of Keen's concern is the International Assessment of Agricultural Science and Technology for Development (IAASTD; http://www.agassessment.org/index.cfm?page=plenary&ItemID=2713). The original intention of this report was to investigate how science and technology could reduce hunger and improve nutrition and sustainability in the developing and third world. Unwisely, the organizer failed to limit contributors to those who could provide a balanced scientific input and instead included a large number with marginal agricultural science connections, including environmentalists (reference [20] outlines environmentalist attitude to scientific knowledge). The title, IAASTD, is now a misnomer; the science unsurprisingly is marginalized and an evident need for scientific research omitted.

The components (minerals, prices, seed, crop and others) that contribute to agricultural yield are linked together in a farming network [4]. Like any network, the sensitivity with which any component can be used to increase yield is dependent on the context within which the farming network is embedded. Long experience has shown, however, that application of scientific and technical knowledge is far and away the most efficient way in which to increase and sustain yield, no matter where the farm is located. Sociology, agroecology, spirituality or any other of the marginal topics dealt with at length by the IAASTD will not put bread on the poor farmer's table, increase food security or stabilize food price when the soil is phosphate-deficient, as many of the African soils are. The government of Malawi simply subsidized fertilizer price, and Malawi now feeds itself. The most sensitive constituent in its agricultural network was simple knowledge of crop growth requirements. The desire of many individuals who are marginal to agricultural science to impose their own political views (under the guise of science and technology) on third world countries in this flawed IAASTD report smacks strongly of the discredited social engineering of the last century.

The International Council for Science produced a much simpler but balanced approach to agricultural sustainability[†] written, of course, by scientists, and the Sasakawa-Global 2000 programme[‡] exemplifies science in practice. For over 20 years this excellent programme organized by Normal Borlaug, father of the green revolution, has tirelessly worked in Africa to provide the highest quality seed to African farmers, to provide demonstration plots illustrating how to improve yields more than fourfold and to provide local agricultural education, local machinery construction and water storage and irrigation. No long, inappropriate, US$12 million dollar, misleading reports; just quietly introducing an African green revolution.

Conclusion

It is essential that all scientists assert the primacy of properly established and critically assessed scientific knowledge not only in the formulation of agricultural policy but in all areas of human activity. If knowledge is not used, only catastrophe will follow ignorance.

References

1 Smil, V. (2000) *Feeding the World,* MIT Press
2 Trewavas, A.J. (2000) The population biodiversity paradox. Agricultural efficiency to save wilderness. *Plant Physiol.* 125, 174–179
3 Faulkner, E. (1943) *Plowmans Folly,* Grosset and Dunlap
4 Trewavas, A.J. (2004) A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Prot.* 23, 757–781
5 Robertson, G.P. *et al.* (2000) Greenhouse gases in intensive agriculture: contributions of individual gases to the radiative forcing of the atmosphere. *Science* 289, 1922–1925
6 Pennisi, E. (2008) The blue revolution drop by drop, gene by gene. *Science* 320, 171–173
7 Carson, R. (1962) *Silent Spring,* Houghton Miflin
8 Simon, J. (1996) *The Ultimate Resource.* Princeton University Press
9 Gribble, G.W. (2003) The diversity of naturally produced organohalogens. *Chemosphere* 52, 289–297
10 Blackman, S. (2005) Industrial pollutants reveal a surprising origin. *Scientist* 19, 24–30
11 Ames, B.N. and Gold, L.S. (2000) Paracelsus to parascience: the environmental cancer distraction. *Mutat. Res.* 447, 3–13
12 Beier, R.C. (1990) Natural pesticides and bioactive components in food. *Rev. Environ. Contam. Toxicol.* 113, 47–137
13 Nilsson, R. (2000) Endocrine modulators in the food chain and environment. *Toxicol. Pathol.* 28, 420–431
14 Morris, S.C. and Lee, T.H. (1984) The toxicity and teratogenicity of solanaceae glycoalkaloids particularly those in the potato. *Food Technol. Aust.* 36, 118–124
15 Batista, R. *et al.* (2008) Microarray analyses reveal that plant mutagenesis may induce more transcriptomic changes than transgene insertion. *Proc. Natl. Acad. Sci. U. S. A.* 105, 3640–3645
16 Federoff, N. (2004) Poisoned Rats or Poisoned Wells. In *Mendel in the Kitchen*, pp. 177–183, Joseph Henry Press
17 Chassy, B. *et al.* (2007) Response to GM soybeans – revisiting a controversial format. *Nat. Biotechnol.* 25, 1356–1358

[†] Discussion paper by the Scientific and Technological Community for the 16th Session of the United Nations Commission on Sustainable Development (CSD-16) Prepared by the International Council for Science (ICSU) (http://www.icsu.org/1_icsuinscience/PDF/SUSTSD_CSD16_ST_Community_Discussion_Paper.pdf).

[‡] Feeding the Future: Newsletter of the Saskawa Africa Association. Issue 23, July 2007 (http://www.saa-tokyo.org/english/newsletter/pdf/issue23.pdf).

18 Catchpole, G.S. *et al.* (2005) Hierarchical metabolomics demonstrates substantial compositional similarity between genetically modified and conventional potato crops. *Proc. Natl. Acad. Sci. U. S. A.* 102, 14458–14462
19 Keen, A. (2007) *The Cult of the Amateur,* Brearley Publishing
20 Wolpert, L. (2000) Friends and enemies of the Earth. *The Times Higher Education Supplement* 1 December (http://www.timeshighereducation.co.uk/story.asp?sectioncode=34&storycode=155557)