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RSC and IChemE joint response to the Royal Society call for evidence on biological approaches to enhance food-crop production.

The RSC and IChemE welcome the opportunity to comment on the Royal Society call for evidence on biological approaches to enhance food-crop production.

Learned organisations such as the RSC and IChemE have a key role to play in the identification of gaps and opportunities for future research.

The RSC is the UK Professional Body for chemical scientists and an international Learned Society for advancing the chemical sciences. Supported by a network of over 44,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public.

IChemE is the hub for 27,000 chemical, biochemical and process engineering professionals worldwide. We are the heart of the process community, promoting competence and a commitment to sustainable development, advancing the discipline for the benefit of society and supporting the professional development of members

If you would like further information or need anything in this document clarified, please do not hesitate to contact me.

Yours Sincerely,
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IChemE heart of the process

Is there a need to increase global food-crop production to support present and future populations and their consumption patterns?

By 2030 the world's population will have increased by 1.7 billion to over 8 billion, bringing with it the need to meet growing calorific demand.[1] This increase in demand is exacerbated by economic growth in the emerging economies of China, India, Brazil and Russia. As these countries become more affluent this will translate directly into increased food consumption, particularly for high value-added food such as meat and diary products[2].

Climate change is predicted to adversely impact food production and compound problems of growing global food demand. World agricultural GDP is projected to decrease by 16% by 2020 due to global warming.[3] Cereal yields are expected to decline in more than 40 developing countries with average losses of 15% and projections show that land suitable for wheat production may almost disappear in Africa.[4]

Around 27% of the total global land mass is estimated to be suitable for rain-fed crop cultivation, with only 10% of it currently in use for this purpose.[5] Although this appears to suggest that there is significant room for expansion of food production, the requirements for human settlements, forest, pasture, and nature reserves means that in practice much less land is available for cultivation. It is possible to bring further land into agricultural production. However this is limited to an additional 5-10% of good quality land[6].

Supported by a persistent, tight supply and demand situation, prices of nearly all food commodities have risen since the beginning of 2008. By March 2008 the FAO Food Price Index averaged 220, 57% more than in March 2007. In addition, increase in oil prices ($135 per barrel in May 2008[7]) has significant implications for food production as pesticides, fertilisers; mechanical equipment, cultivation, and distribution are largely reliant or derived from oil.

The RSC and IChemE believe that global food production must improve efficiency and increase yields to support future populations and their consumption patterns.

Which current/future husbandry or farm management technologies for the enhancement of food-crop production are appropriate for development and dissemination and why? Comments could include information on the benefits they may bring, difficulties in scaling up their use in different parts of the world and time needed to get improved methods incorporated in farm practices.

Maintaining good soil structure is important to ensure high productivity. The yield of crops is often directly related to the amount of nitrogen and other nutrients available either from natural sources such as nitrogen fixing bacteria working in symbiotic relationship with

[1] 2004: UN World Population to 2030, United Nations, NY
[2] 2006:OECD – FAO Agricultural Outlook 2006-2015
[3] IFPRI (2007) IFPRI's Biannual Overview of the World Food Situation presented to the CGIAR Annual General Meeting, Beijing, 4 December 2007, The International Food Policy Research Institute
[4] Fischer *et al.* (2005) Socio-economic and climate change impacts on agriculture: An integrated assessment 1990-2080, *Philosophical Transactions of Royal society B*, **360**, 2067-2083.
[5] Chatham House (2008) UK Food Supply: Storm Clouds on the Horizon? Chatham House, London.
[6] 2004: UN/FAO statistics
[7] BBC (2008) Oil soars to new record over $135, 22 May 2008. BBC News, London. See http://news.bbc.co.uk/1/hi/business/7414093.stm

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legumes, the addition of organic matter (primarily manure) to the soil and applied nitrogen fertiliser. However, not all the available nitrogen is used by the plant: there are also de-nitrifying bacteria in the soil which produce nitrous oxide, which has recently been recognised as a significant contributor to global warming and as presenting potential problems with diffuse pollution of water courses. Various approaches have been developed in the past few decades to minimise the environmentally detrimental effects of agricultural production. Technologies such as low-till or no-till and the use of cover crops are important.[8] These techniques reduce the demand for energy and water by reducing evaporation; raising the carbon content of soil; improving soil structure; increasing earthworm populations; and combating wind and water erosion. Since the introduction of cover crops, no-till acreage has increased by nearly 40%.[9]

Farmers are increasingly adopting integrated crop management (ICM) schemes to maximise productivity and minimise a crop's vulnerability to pests and diseases. This entails using "best practice" through the use of the best crop varieties and husbandry, adopting the best cropping patterns and habitat management and the appropriate use of nutrients (integrated plant nutrient systems, IPNS) and integrated pest management (IPM).

IPNS aims to use an understanding of soil nutrients and biochemistry, in order to improve the precision of inputs to enhance productivity under changing conditions, whilst minimising the potential environmental impact from the use of especially nitrate and phosphate fertilisers. Improving the efficiency of nutrient uptake and utilisation is the challenge of the future.

IPM aims to avoid or reduce the loss of yield due to pests while minimising negative effects of pest control by a management process that applies the most appropriate pest control methods and strategy to each situation. IPM promotes primarily biological, cultural and physical pest management techniques, and uses chemical ones only when essential. The uses of crop protection products is particularly important in the management of insects and fungal diseases as last line of defence, as resistance development can leave the farmer with limited or no control measures.

The RSC recognises that the lack of information on agro-ecology and the high demand for management skills are major barriers to the adoption of sustainable agriculture worldwide.

Do you anticipate/foresee any advances in engineering, materials science, chemistry or other non-biological science that will strongly influence future developments in food-crop production?

Future advances in the chemical sciences and chemical engineering will enhance production and address the challenges of increasing yields from existing agricultural land through enhanced responsiveness to fertilisers and pesticides.

The challenges can be broken down into five categories:

[8] Reganold, J.P. & Huggins, D.R. (2008) No-Till: How Farmers Are Saving the Soil by Parking Their Plows. Scientific American
[9] Avery, A. (2004) The Power and Promise of Agricultural Biotechnology. Center for Global Food Issues, Churchville, VA, USA. See www.cgfi.org/2004/11/07/the-power-and-promise-of-agricultural-biotechnology.

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1. Pest control: up to 40% of agricultural productivity would be lost without effective use of crop protection chemicals[10]. Agriculture is facing emerging and resistant strains of pests, thus the development of new crop protection strategies is essential.

- New high-potency, more targeted agrochemicals with new modes of action that are safe to use and environmentally benign.
- Formulation technology to ensure a consistent effective dose is delivered at the right time and in the right quantity.
- Development of pesticides using pheromones, semiochemicals and allelochemicals as starting points for pest control strategies.

2. Plant science: increasing yield and controlling secondary metabolism by better understanding plant science.

- Understanding and exploiting biochemical plant signals for the development of new crop defense technologies.
- Improvement in the understanding of carbon, nitrogen, phosphorous and sulfur cycling to help optimise carbon and nitrogen sequestration and benefit plant nutrition.
- Understanding plant growth regulators.
- Development of plants with improve nitrogen use efficiency
- Secondary metabolites for food and industrial use.
- Understand the impact of nutrients at the macro and micro level.
- Exploiting the outputs of this understanding using biotechnology.

3. Water: coping with extremes of water quality and availability for agriculture.

- The use of grey water in agriculture.
- Targeted use of water in agriculture (drip delivery)
- Development of drought tolerant plants.

4. Soil science: understanding the structural, chemical and microbiological composition of soil and its interactions with plants and the environment.

- Development of fertiliser formulations able to improve the retention of nitrogen in soil and uptake into plants.
- Optimisation of farming practices by understanding the biochemistry of soil ecosystems, for example the chemistry of nitrous oxide emissions from soil, the mobility of chemicals within soil, and partition between soil, water, vapour, roots and other soil components.
- Improved understanding of methane oxidation by bacteria (methanotrophs) in soil to help in the development of methane-fixing technologies.
- Understanding soil structure, material mechanical properties of soils and nutrient flow.
- Low energy synthesis of nitrogen and phosphorous-containing fertilisers. Finding alternatives to the Haber-Bosch process

5. Effective farming: minimising inputs and maximising outputs through agronomic practice.

- Development of rapid *in situ* biosensor systems that can monitor soil quality and nutrients, crop ripening, crop diseases and water availability to pinpoint nutrient deficiencies, target applications and improve the quality and yield of crops.

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[10] Oerke, E.-C. Dehne, H.-W. Schonbeck, F and Weber, A (1994) Crop Production and Crop Protection, Elsevier Science

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- Analysis of climate change parameters, e.g. greenhouse gases and seawater salinity, generates input for predictive models, which can identify changing conditions for agronomy providing valuable data for the planting of new crops.
- Precision agriculture at the field level.
- Engineering tools (e.g. sensors) for on farm practices e.g. grain drying, seed treatment, and crop handling.
- Re-introduction of farming advisers to spread best practice rapidly and effectively

A timeline of the chemical science and chemical engineering research priorities for food-crop production can be found in figure 1.

What are the potential barriers to the application of biological approaches to enhance food crop production? These barriers might include matters relating to regulation, national and international policies, adequacy of the skills base, research infrastructure and resource availability including germplasm conservation, and knowledge transfer and intellectual property issues.

The solutions to enhancing food-crop production are not simple, they will only be found by highly trained people working and leading in the food supply chain industry with the appropriate technical background. Only by understanding these problems in scientific and technological terms will the solutions be obvious to those with the power to initiate the required changes across the food chain. Currently the UK does not have an adequately skilled workforce to meet the challenges outlined in this submission.

Whilst education, training and research are the province of the public sector, it must be recognised that the majority of food production, manufacture and distribution is in the hands of the private sector. The necessary competition for profit will need to be tempered with collaboration if any of the overarching issues are to be successfully tackled.

There is much confusion amongst employers, potential employees, schools and other interested parties surrounding the profile and breadth of opportunities within the food production sector. Improvements are necessary in the training of careers advisers and the information resources available for secondary school students, specifically regarding the possible career paths open in modern food production. Promotion of career opportunities by the food supply chain sector, through work experience placements, teaching placements, careers events and media engagement will also be required.

Regulation possibly has a bigger role to play in food than in any other industry. EU food legislation, particularly with respect to the use of chemicals, outputs of chemical sciences and 'novelty' is highly complex and presents significant barriers to rapid approval of new developments and concepts. The precautionary principle is used as the approach to decision-making in the EU, particularly on issues related to food safety and approval of new materials, methods, processes or technologies to the detriment of innovation.

Regulation should be based on risk, as demonstrated by the EU regulatory framework for chemicals: Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (1907/2006). Substances should generally not be banned on the basis of intrinsic hazard alone. Intrinsic hazard is not a good measure of the actual threat that a substance poses to

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humans or the environment. Risk (which requires both hazard and exposure) is a better measure because it is based on the likelihood that an intrinsic hazard associated with a substance will cause actual harm. However, it must be recognised that perceptions of risk differ widely within society and around the world.

The Royal Society of Chemistry and the institution of Chemical Engineers are pleased for this response to be publicly available and will be shortly placing a version on www.rsc.org. Should the Royal Society have any queries regarding this response then they should in the first instance address them to Farrah Bhatti, RSC, Burlington House, Piccadilly, W1J 0BA email: bhattif@rsc.org

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