Crop Protection
Association

AGRICULTURE 4.0

The next agricultural revolution

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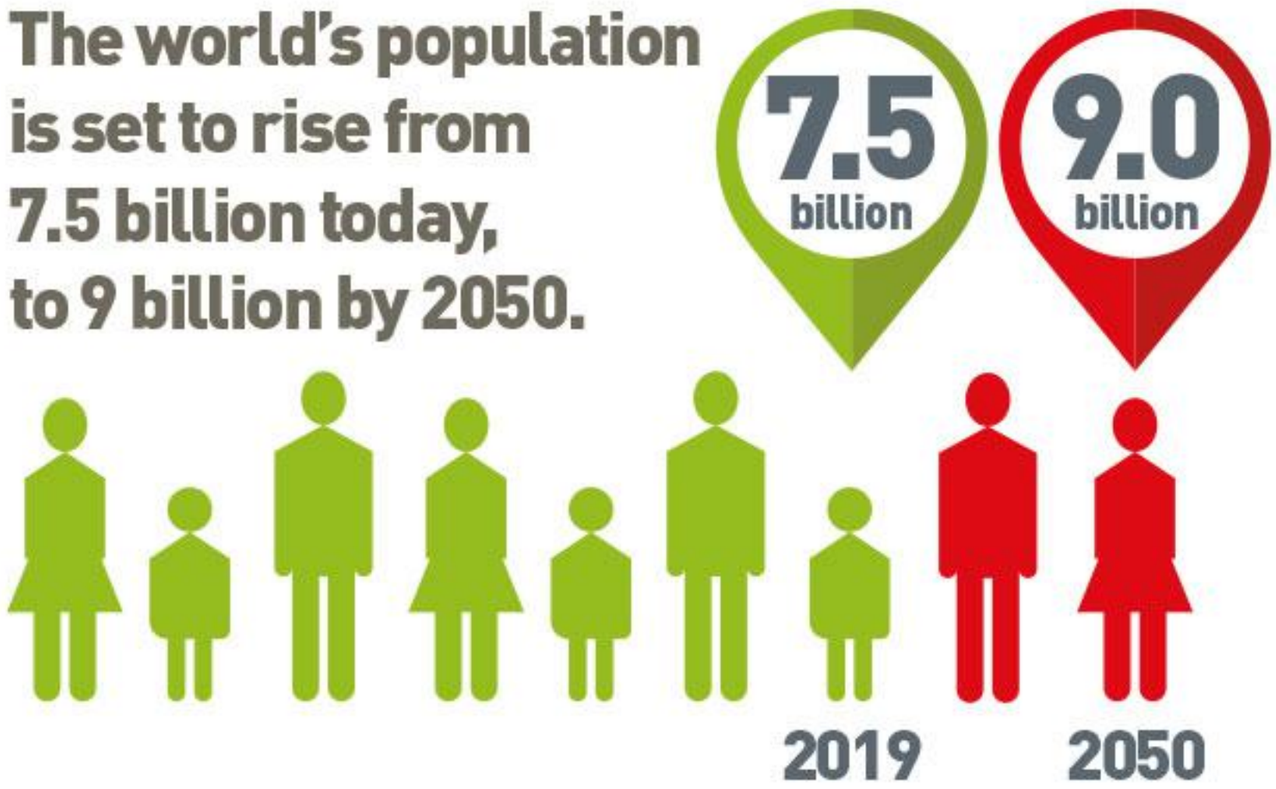
Change is coming **in agriculture**

The world has seen some remarkable developments since mankind started to farm; the move from hunter gatherer to agrarian society, improvements in crop rotation and the use of waste as fertiliser, through to the "Green Revolution" and the development of synthetic fertilisers and crop protection products, which is estimated to have saved a billion lives in the post-war years.

We stand on the threshold of the Fourth Agricultural Revolution, where advances in science and agricultural technology will ensure a supply of plentiful, affordable food, whilst reducing the impact on the environment and leaving space for nature.

This is essential if we are to meet the challenge of feeding a global population expected to rise from 7.5 billion today to 9 billion by 2050 in the face of climate change and competition for finite natural resources.



The challenge for UK farmers will be to produce increasing quantities of nutritious and healthy food, while at the same time making significant environmental gains including improving soils, saving water and reducing carbon emissions. There are hugely exciting new developments in science and technology which can help make this vision a reality.

The Crop Protection Association represents the makers of the insecticides, herbicides and fungicides which help farmers produce healthy and plentiful crops. Our industry is unusual in that many of the leading participants are looking for ways in which the volume of their products used on farms can be reduced, while achieving even better outcomes for farmers. Success will depend to a large extent on how well we use science and technology in the future.

Our food crops have to compete with 30,000 species of weed, 10,000 species of insect pests, and countless diseases. Without crop protection, these natural pests would reduce our food supply by around a third. By reducing crop losses and producing higher yields we can pursue a "share and spare" approach of producing more food from less land, leaving more room for field margins and increased biodiversity. By integrating managed field margins, woodlands and waterways we can create rich, connected wildlife habitats.

We acknowledge that consumers may have concerns about the use of new agricultural technologies and in the past companies have not done all they should have done to engage in an informed discussion about the safety and efficacy of the products they make.

Food is such a central part of not just our lives but our emotions, our relationships and our culture. We are all bombarded with so many different messages about the food we eat that it can sometimes feel overwhelming. We recognise that a discussion about science in agriculture needs to also consider the values that people hold about their food. For the potential of the Fourth Agricultural Revolution to be fulfilled industry, farmers and consumers will need to understand each other much better than they have in the past.

For thousands of years mankind has sought better ways to grow crops. Some of the best ideas are old ideas, such as crop rotation and plant breeding. But in the early twenty first century there are remarkable opportunities being generated by new science and technology. And we must not ignore those opportunities if we are to provide future generations with plentiful, healthy food and a rich natural environment.

"We stand on the threshold of the Fourth Agricultural Revolution"

Executive **Summary**

In this report we have set out some of the most important developments in agricultural technology which will contribute to the Fourth Agricultural Revolution and help meet the challenge of increasing food production by 50%.

We summarise these developments below.

Integrated Pest Management (IPM)

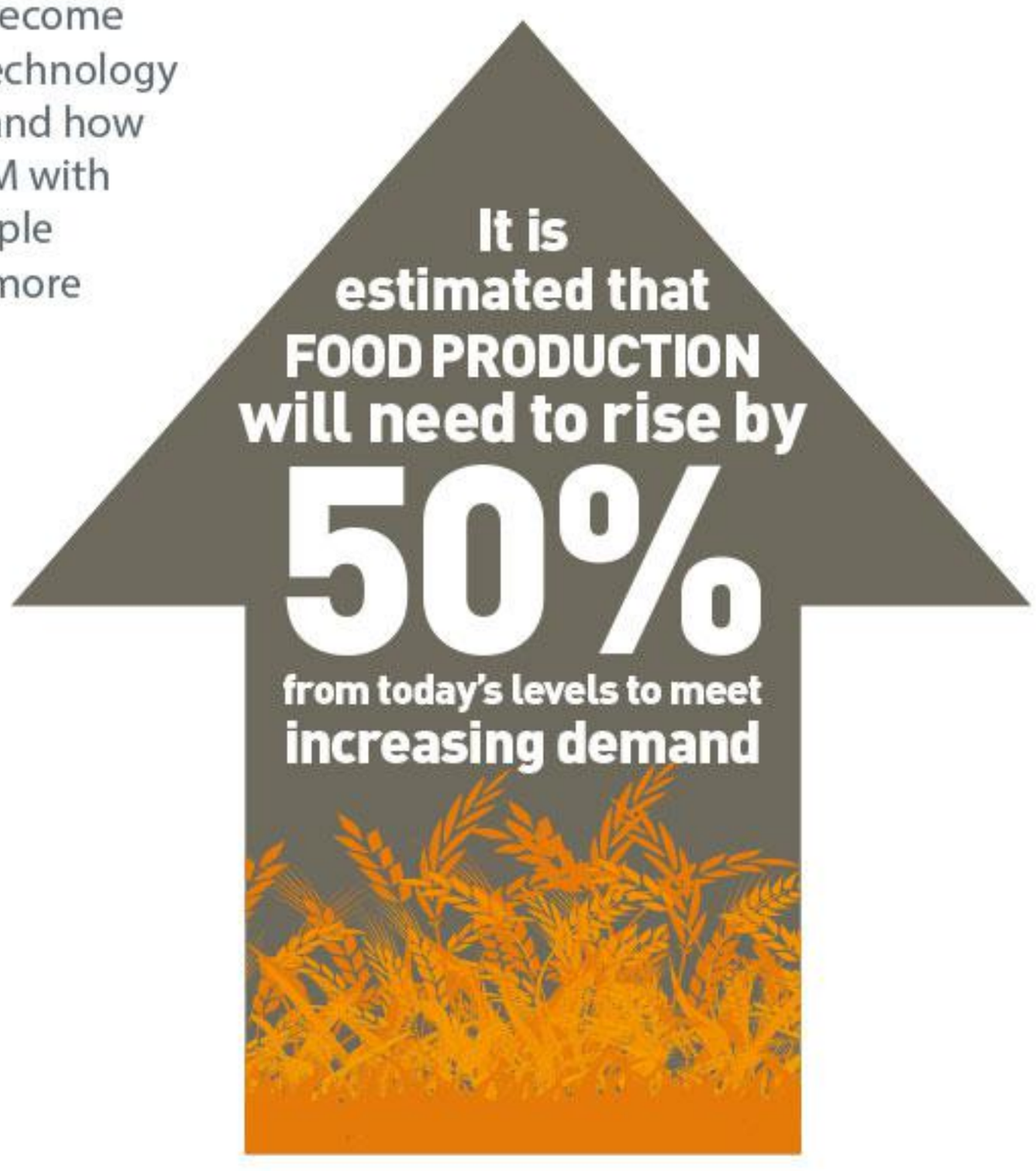
The underlying approach to protecting our crops will continue to be integrated pest management. This is a holistic approach which uses all available plant protection methods to discourage the development of weed, pest and disease populations. It is an approach actively supported by the Crop Protection Association through the Voluntary Initiative, under which farmers, water companies and crop protection companies work closely together to keep the use of pesticide and other interventions to levels that are economically and ecologically justified and minimise risks to human health and the environment.

IPM encourages the use of crop rotation, field borders, crop selection and cultivation techniques which reduce the need for chemical interventions. It recognises the threat that pests of all types can become resistant over time. Science and technology are enabling us to better understand how resistance develops and to use IPM with increasing effectiveness, for example by using crop rotation in a much more targeted way.

Smart crop protection

Crop protection is evolving rapidly. Deeper understanding of crops and pests at a genetic level is transforming the way that we safeguard our food supplies. This means that research into the crop protection products of the future can be much more targeted to deal with specific threats. Some of these will come from natural or so-called biological interventions, but once again, it is the improved understanding of the genetics of plants and insects which opens new possibilities for so-called bio-controls.

Smart crop protection also involves finding ways to apply treatments much more precisely. Using a toolkit which includes satellite information (GPS), drones and increasingly sophisticated agricultural machinery it is becoming possible to apply pesticides much more precisely and achieve more with less.



Innovative plant breeding

New technology is transforming the science of breeding new varieties of crops which will be more sustainable and productive. Improvements in understanding the DNA of plants will greatly reduce the trial-and-error involved in creating improved varieties. The technique of gene editing - removing carefully targeted pieces of plant DNA to produce varieties which are more productive and less prone to disease - offers huge potential for the future. However, the future use of gene editing inside the European Union will be severely limited by a recent judgement of the European Court of Justice.

Big Data

The ability to process huge amounts of digital information - Big Data - will be a game-changer for agriculture. It is already improving the way in which research into new varieties and crop protection products is conducted. And increasingly it is changing the way in which farmers are able to monitor what is happening in their fields and then to shape the ways in which they respond.

The Big Data revolution will be part of a transformation of agriculture in the UK and around the world in the 21st century.

The Crop Protection Association (CPA)

The Crop Protection Association (CPA) is the voice of the UK plant science industry, promoting the essential role of science and innovation on protecting food, parks, gardens, roads and railways. We advocate for good stewardship, better regulation and best practice.

Crop Protection Association

Our members are involved in the development and manufacture of a wide range of plant science technologies which are of crucial importance to the cultivation and protection of food crops, protecting our gardens, woodlands, infrastructure and public places. These include the formulation and manufacture of synthetic and bio pesticides, seed and plant breeding and agricultural biotechnology.

The use of pesticides is carefully managed to avoid unacceptable risks to humans, animals and the environment. Pesticides are subject to stringent regulation. We have recently published an independent report outlining the options for regulation of crop protection products post Brexit.

CPA represents 23 member companies, which account for 96% of sales of crop protection products in the UK.

[1] Regulation of Plant Protection Products in the UK after Brexit, Exponent

Smart crop protection
for smart farms

Farmers have always walked their fields to examine the health of their crops and they will continue to do so far into the future. But modern technology is transforming the ability of growers to monitor what is happening in the fields and respond precisely.

Satellite (GPS) technology in farm machinery is increasingly commonplace. Sensors can monitor the moisture and nutrients in soil in great detail so that planting can become much more precise. And drones can be used to provide pictures of fields from the air in sufficient detail to distinguish between crops and weeds.

The "Hands Free Hectare" project has illustrated what is becoming possible as technology improves. A crop of barley was successfully grown in the UK without anyone ever setting foot in the field. It was done by using a tractor and combine equipped with cameras, sensors and GPS systems. The field was monitored by drones and a robot collected plant samples for inspection.

We are moving rapidly into an era in which these new technologies will play a key role in monitoring of crop health and application of crop protection.

Improved threat surveillance

In order to guard against disease and damaging insects it is essential for farmers to have constantly updated information about the threats to their crops.
One example of the new technology under development is the LIDAR. It points a laser beam through a growing crop and, as insects fly through the beam, it can count them and distinguish between insects which are harmful to the crop and beneficial insects such as honey bees. By scanning the whole field the LIDAR can see where there are concentrations of harmful insects so that the field can be sprayed with insecticide in affected areas, but not in places where there are low concentrations of harmful insects or high concentrations of beneficial insects.

In addition to advances in in-field surveillance, new technologies are being developed to understand nationwide threats. One example in the UK is the Centre for Crop Health and Protection (CHAP) which has been set up as part of the government's Agri-Tech Strategy. It has created "CropMonitor" which provides forecasts for pests and diseases of wheat, barley, oilseed rape and potatoes using a bespoke weather monitoring network, national pest and disease surveillance data and advanced risk models.

“We are moving rapidly into an era in which these new technologies will play a key role in monitoring of crop health and application of crop protection”

Precision application

The aim of all crop protection is to target pests as precisely as possible, for example, rather than using pesticides on a whole field, to pinpoint the parts of the field which are in need of treatment. This reduces the amount of pesticide which is used and thus slows the development of resistance in pests.

Developments in robotics are taking the precise application of crop protection products to new levels. Sensing systems are being developed which will enable machines to identify plants in a field and clearly differentiate between a weed and a crop.

Having identified the weeds, machines will be able to apply pesticides precisely on to the leaves of the weeds, thus reducing the overall volume of pesticide use dramatically. New research is also improving the precision with which droplets of pesticides stick to plant leaves rather than splashing as they are sprayed.

This kind of precision weeding (or hyper-weeding) is already used for greenhouse crops where growing conditions are closely controlled, but has potential for much wider usage in future.

Biological controls (biocontrols)

Synthetic chemicals are only one of the ways in which pests can be controlled. There are an increasing number of biological controls which can be highly effective in some circumstances. In recent years crop protection companies have increased research and development into biological controls. With the additional research resources which major players in the industry can provide it is expected that the market in biological controls will expand rapidly.

Pesticide makers are increasingly using naturally occurring substances - so-called bio-pesticides - to control threats to crops. For example, garlic extract can be used to control harmful nematodes. And applying micro-organisms such as viruses, fungi and bacteria can be used to control pests like caterpillars in vegetables and orchards.

Advances in computational tools and machine learning are bringing rapid advances in the understanding of the way in which microbes applied to seeds can improve crop yields and reduce disease. The market in "agricultural microbials" is expanding very rapidly as new technology improves its efficacy.

Another long-standing biocontrol strategy is the introduction of beneficial insects or predators – so called natural enemies such as ladybirds, lacewings and parasitoid wasps. The use of biocontrols is becoming more and more targeted. For example, insect sex pheromones can be used for "lure and kill" strategies which attract pests to pesticide deposits and thus reduce the need for spraying.

“Developments in robotics are taking the precise application of crop protection products to new levels”

Innovative plant breeding

Mankind has been breeding plants for hundreds of years, but improved understanding of genetics and molecular biology have transformed traditional techniques. Using predictive breeding processes and new technologies allows plant breeders to accelerate the launch of precisely designed new varieties. Such developments are essential to improve yields and make crops more resilient to the impact of climate change. Improvements in plant breeding can improve global food security by increasing the nutritional value of crops, as well as their resistance to drought and disease.

With increasing success in predicting outcomes, the old trial-and-error approach is being replaced. Advances in computer modelling are helping breeders to predict the characteristics of new varieties. Using gene editing techniques (see below) in a laboratory can further speed the research process, even where the final product is a seed which has been bred by conventional techniques and does not itself contain any gene edits.

In the UK, research by Syngenta has recently led to the introduction of new hybrid barley varieties, which have already been widely adopted. New hybrid wheat varieties are in the later stages of development with the expectation that they will be launched at the turn of the decade in key wheat growing areas of Europe, Asia and North America.

Gene **editing**

Gene editing involves the precise replacement of one DNA sequence with another. It is different from genetic modification (GM) in that GM has traditionally involved the introduction of DNA from other organisms.
Gene editing involves making small alternations to DNA without introducing "foreign" genetic material. The changes made are indistinguishable from naturally occurring mutations.

Gene editing provides opportunities to develop new crop varieties which are resistant to disease or able to thrive in challenging climates. This scientific technique has already been used to develop new varieties of potato which are resistant to late blight. These potatoes are also less susceptible to bruising, which reduces a large amount of waste in the food chain and makes potato farming significantly more sustainable. Gene-edited potato varieties have passed rigorous health and environmental checks in the USA and Canada and are now being grown commercially.

There is great potential for gene editing to provide better outcomes for human health and the environment. But a recent court ruling means that potential is unlikely to be realised within the EU.

In July 2018 the European Court of Justice (ECJ) ruled that gene editing should be subject to the same restrictions as traditional genetic modification. Those restrictions have had the effect that GM crops have never been grown at commercial scale in the UK, while in many parts of the world genetically modified seeds have been widely used for more than two decades. For example, almost 80% of the world's soybeans are grown from genetically modified seeds. GM soybeans are imported into the EU in large quantities for use in processed foods and animal feeds.

After the ECJ ruling it appears likely that the potential benefits of gene editing will be taken up elsewhere in the world while being denied to EU farmers.

“Gene editing provides opportunities to develop new crop varieties which are resistant to disease or able to thrive in challenging climates”

A new world of **Big Data**

Understanding why a crop produces a bumper harvest one year but does less well the next, or thrives in one field but fails in another, has always been at the heart of successful farming. But we now have vast amounts of data from farms all over the world which can be used to reach evidence-based conclusions where previously farmers relied on personal observation or instinct.

The amount of data available multiplies every year and the challenge is to organise the data in ways which can be used to improve the yields and sustainability of future farming. The Government's Agri-tech strategy has created Agrimetrics, which will create ways to integrate data platforms.

At an international level data sharing is being facilitated by GODAN, the Global Open Data for Agriculture and Nutrition, set up in 2013.

Big Data, as it is often called, is now influencing every area of farming and crop protection, from the analysis of the efficacy of different seeds and treatments to identifying new potential active ingredients by understanding pests at a molecular level.

In future Big Data will increasingly help us to understand and improve soil health. A single gram of soil contains around 10 billion bacterial cells. Data analysis will help us to understand which species are present, which species influence which other species and which species are responsible for which biological activities.

a cubic centimetre OF SOIL

like this  **contains**

10,000,000,000

[ten billion - bacterial cells]

Soil management

Improving the quality and health of the soil is at the heart of sustainable farming. Traditional techniques such as crop rotation have an essential role as does the use of "cover crops" to break up the soil between plantings of crops such as cereals.

" Increasingly techniques such as "no till" are being used to minimise soil disturbance and promote worm activity"

Reducing the amount of tillage has benefits not only in reducing the compaction of the soil by heavy machinery but in reducing carbon emissions from farm equipment.

In order to improve soil health it is essential to analyse how it develops over time, for example during a cycle of crop rotation. The Soil Health facility at the Centre for Crop Health and Protection (CHAP) - developed as part of the UK Government's Agri-tech Strategy - provides an opportunity to grow crops in carefully controlled conditions while analysing the impact on soil in minute detail.

At a simple practical level it is now becoming easier for farmers to detect harmful bacteria in soil before they start to damage crops. A UK start-up company (FungiAlert) has developed a small, low-cost probe which can detect the spores of harmful micro-organisms which cause crop disease. With precise analysis of the threat, farmers can then use crop protection products in a much more targeted way.

Vertical **farming**

As well as improving knowledge of soil health, there is a fast developing understanding of how crops can be grown without soil. Hydroponic growing techniques, using just water and fertiliser, are already used for some products such as salad leaves and herbs.

Increasingly hydroponic agriculture is being used to create so-called "vertical farms". These use hydroponic farming techniques to grow crops in trays stacked above one another. Former industrial premises can be utilised and by placing these close to supermarkets and other points of sale the product will be fresh and "food miles" negligible.

The environment inside vertical farm buildings can be carefully controlled to exclude insects and diseases which might damage plants and typically no conventional crop protection products are required. Current developments include the use of robots and conveyor belts to harvest the crop.

The need for constant temperatures and bright light to promote plant growth have been constraints on the use of such techniques and led to claims that this type of farming increases CO_2 emissions. But hydroponic agriculture uses less water and fertiliser than conventional farming. And the refinement of low energy LED lighting technology and renewable energy are helping to make vertical farming a much more promising technique for growers. Vertical farming is now attracting major venture capital investors from the high tech sector in America.

Increasingly hydroponic agriculture is being used to create so-called "vertical farms"

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