Cereal production in the United Kingdom (UK) with regulation, resistance and a changing climate

Keith Norman.

Independent Agritech Consultant; Keith Norman Consultancy Ltd..

Keywords

- regulation, resistance, yield plateau, yield gap, remote sensing, soil health, soil nutrition, fungicides, immune enhancers, semiochemicals, robotics, big data.

Take home messages

- Reliance on conventional pesticides will diminish from the effects of regulation and resistance.
- Plant breeding and genetics have a vital part to play in the sustainability of crop production.
- There are many emerging applied technologies that will underpin the sustainability of future crop production.

Regulation

The European Union (EU) has one of the most heavily regulated agricultural industries globally. The United Kingdom (UK)'s agrochemical (Agchem) market is affected by all of the following regulations:

- Regulation 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Regulation 1107/2009 on the Placing on the Market of Plant Protection Products (PPPR). Aims to draft 'specific scientific criteria for the determination of endocrine disrupting properties'. Deadline was originally 2013, the criteria were adopted only in 2018.
- Regulation 528/2012 on Biocidal Products (BPR).
- Regulation 2018/605 Endocrine Disruption.
- Regulation 2000/60 Water Framework Directive.

In 1993, the EU launched a review of approximately all of the 1000 active substances in the EU.

Each substance had to be evaluated with respect to human health (consumers, farmers, local residents and passers-by) the environment, groundwater, and non-target organisms, such as birds, mammals, earthworms and bees. This review program was finalised in March 2009. Some manufacturers decided not to submit dossiers. Some products were no longer profitable, or the active substances would not pass the stricter safety testing requirements. Only 26% of the actives survived the review.

Table 1. Active ingredients that are no longer available.

Chlorothalonil	Carbendazim	Diquat	CIPC	Fenoxaprop
Neonicotinoids	Methiocarb	Flupyrsulfuron	Flurtamone	Flusilazole
Fenpropimorph	Fluazifop	Iprodione	Isoproturon	Linuron
Glufosinate	Ioxynil	Paraquat	Permethrin	Picoxystrobin
Mecoprop	Omethoate	Simazine	Tepraloxydim	Terbutryn
Quinoxyfen	Quizalofop	Tralkoxydim	Tridemorph	Vinclozolin
Thiamefoxam	Thiram	Desmedipham	Dimethanamid	Gamma HCH

Active Ingredients that are considered high risk of being removed in the next two to three years:

Fungicides Epoxiconazole, Tebuconazole, Cyproconazole, Metconazole, Mancozeb.

Herbicides 2,4-D, Bifenox, Carbetamide, Chlortoluron, Clopyralid, Fluroxypyr, Glyphosate (Austria, France and Germany have already announced a ban), Metazachlor, MCPA, Pendamethalin Propyzamide.

Insecticides Cypermethrin, Deltamethrin, Esfenvalerate, Thiacloprid, Metaldehyde.

What have been the effects of this more stringent system?

Tougher regulation has led to manufacturers submitting less actives for approval.

During the 1990s over 120 new actives were submitted for approval, but this has reduced to less than 40 in the last decade.

Because of the more stringent criteria the costs of bringing a new active to market has increased from $184m in 2000 to $286m (current). Maximum Residue Levels, Ecotox, Environmental Chemistry and Toxicology are some of the significant costs of registering a new product.

There is a much greater threat of resistance development due to fewer modes of action being available for fungicide, herbicide and insecticide options, and therefore, increased selection pressure on what remains.

Active ingredients (AIs) with a single site of action are more favoured in the new system and are more vulnerable to forming resistance than the broad-spectrum multiple site of action AIs.

The manufacturer pipeline of new actives does not seem likely to deliver a wide range of replacement AIs.

Biological controls are in their infancy and are not ready for scale up. They are also very poorly understood and early indications of their performance reliability is hugely variable and weather dependent.

What are UK growers doing to mitigate the dwindling stock of effective plant protection products?

Strategies used by UK growers to mitigate dwindling stock of effective plant protection products:

- Choosing varieties with greater disease resistance.
- Seeding later which reduces disease potential.
- Being more selective of where they grow crops on the farm. They don't grow crops on areas with heavy weed burdens, or inherently less productive areas due to topography, soil type, drainage, etc. Environmental payments are going to take the place of subsidies, the details are yet to be announced.
- Growing more barley and less wheat. It's cheaper to grow and yields are sometimes as good as wheat.
- More spring cropping; which enables an increase in use of non-selective grass weed herbicides and spreads autumn workload.
- Spring beans, spring barley and maize for anaerobic digestors have had the most significant increases.
- The Environmental Land Management Scheme will replace subsidies and will generate income on less favoured areas for crop production.
- Reduce the area of combinable crops and rent land out for potato, sugar beet and vegetables on short-term agreements.
- Greater use of high-technology monitoring tools. For example, DNA fungal spore detectors, insect suction traps, remote sensing using unmanned aerial vehicles (UAVs), satellites, etc.
- Decision support modelling is being developed to use the information from the new Internet of Things together with location, weather, cultivars and the growth period.
- Investigations into the many biological products coming onto market is beginning to take place. In the last three years, registration applications for biologicals have been greater than conventional chemistry.

Resistance in the UK

Resistance is becoming more widespread and at a faster rate of development than ever before. The following are examples of major resistances UK growers are having to manage.

Fungicides	Herbicide	Insecticide
Septoria	Blackgrass	Grain aphid
Mildew	Ryegrass	Peach Potato Aphid
Light Leaf Spot	Poppy	Cabbage Stem Flea Beetle
Potato Blight	Chickweed	Pollen beetle
	Mayweed	Pea and Bean Weevil

Repeated use of a smaller number of active ingredients adds more selection pressure to the remaining options.

Over the last 20 years, we have seen the efficacy of triazoles in a protectant and curative capacity drop significantly from > 90% from when they were first introduced to approximately 30% today.

In more detailed studies, the EC_{50} (effective concentration) of the two key triazoles; epoxiconazole and prothioconazole have steadily increased from 0.01ppm to 5ppm for epoxiconazole, and from 0.001ppm to 1.5ppm for prothioconazole.

It is common to find the coexistence of between five to eight resistant populations in the one field. Not only are there mutations to the CYP51 protein that the triazoles bind to, but there are also two other types of resistance becoming commonplace; an over-expression gene whereby the mutated protein amplifies to greater levels than normal. There is also a mutation that affects the Efflux pump mechanism, whereby the Septoria cells actively pump out the fungicide from within to minimise the effect of the fungicide on them.

Likewise, we are seeing a marked reduction in the efficacy of succinate dehygrogenase inhibitors (SDHIs). From 2015 to 2019, their average performance had dropped from >90% to approximately 60%

The increase of resistance to pyrethroids is also concerning, especially now that neonicotinoid seed treatments are no longer permitted. It is estimated that between 30-50% of grain aphids (English Grain Aphid, *Sitobion avenae*) now carry the KdR gene. This is also reflected in the decrease of the area sown to oilseed rape due to the lack of control of the Cabbage Stem Flea beetle (*Psylliodes chrysocephalus*). Oilseed rape (OSR) grown in the UK has dropped from 758,000ha in 2012 to an estimated 483,00ha for harvest 2020.

Autumn 2019 saw the arrival of the first barley yellow dwarf virus (BYDV) resistant wheat from RAGT, a variety called Wolverine. Wolverine's resistance originates from a goat grass, *Thinopyrum intermedium*, a distant wheat relative. A genetic segment from Thinopyrum containing the resistance gene Bdv2 has been translocated onto a wheat chromosome via an Australian research line known as TC14.

Myzus persicae is totally resistant to pyrethroids causing problems for virus control in potatoes and sugar beet There are two BYDV resistant barley varieties and six TuMV resistant OSR varieties on the market presently.

Grass weed herbicide resistance, principally black grass and ryegrass, is a significant problem on approximately 1M hectares of wheat (50% of the UK hectarage) Both target site and enhanced metabolic resistance coexist within fields. We are beginning to see resistance building with some of the residual chemistry too; flufenacet and pendimethalin.

Of greatest concern is the observation of some blackgrass populations now becoming insensitive to doses of 540g/ha of glyphosate which would normally have been effective.

Finally, there are four broadleaved weed species that are now resistant to sulfonylurea herbicides, they are poppy (*Papaver somniferum*), chickweed (*Stellaria media*), mayweed (*Matricaria*) and sowthistle (*Sonchus asper*).

The Yield Plateau

The phenomenon of the 'yield plateau' extends further than just the UK. A similar situation exists in other countries of Western Europe. From 1980 to 1996, UK wheat yields improved rapidly; by an average of 0.10t/ha per year. Since then, yields have stagnated, increasing by only 0.05t/ha per year.

No single agronomic factor has had a clear dominant influence on trends in UK wheat yields over the last 30 years. A proportion of the lost yield improvement remains unexplained, with aspects of climate change being amongst the likely causes. Plant breeding has continued to deliver genetic improvement.

Several theories have been put forward as to why yield has plateaued such as soil health, soil management and cultivations, compaction from heavier machinery, suboptimal nitrogen (N) and sulphur use, pesticide resistance, sowing dates and seed rates.

The Yield Gap

There is a considerable 'yield gap' between average UK wheat yields, currently approximately 8.5t/ha and the top achieving growers. In 2019, the top Yield Enhancement Network (YEN) of growers reported an actual yield of between 14t/ha to 16t/ha, with the world record still set at 16.5t/ha.

According to YEN, 75% of yield variation is influenced by the farm's physical characteristics, crop husbandry, the agronomist and the farmer. High biomass and ear numbers are essential for high yields. The foundation period; seeding to GS31, is a very important period and crop development within this period is very heavily influenced by soil management, nutrition and good root development.

Moisture retentive soils are key to ensuring grain fill is optimum. There is a positive association with organic amendments, particularly slurry and digestate. Site, weather and husbandry factors have a bigger influence than variety choice, and therefore, varieties should be chosen for quality traits, end markets, disease resistance and standing ability rather than just yield.

There is a positive association with soil pH and with straw incorporation. The association with N fertiliser rate is very strong.

Early indication is that phosphate (P) grain content is also correlated to yield, the critical value for grain P = 3200mg/kg.

There is a negative association with liquid N probably due to the scorching of the crop if it is applied in the wrong conditions. Because high biomass and ear numbers are important, plant growth regulator (PGR)-use has a strong positive association with yield. High straw N% and soluble stem carbohydrate reserves were considered very important to maintain photosynthesis during grain filling.

New technologies being introduced

There are several new technologies being developed which will hopefully increase production potential.

Plant breeding and genetics

The first BYDV resistant wheat and barley in the UK has previously been discussed within this paper. However, there are also exciting developments using a Synthetic Hexaploid breeding approach whereby one of the three wheat genomes, the D genome, is being replaced from other sources of material resulting in greater yields, and greater resistance to biotic and abiotic stress.

Work at the John Innes Centre is also looking at producing grains with increased length and width, thereby increasing the 'sink' for higher yields. Other attributes are also being researched, for example; longer spikelets that produce approximately 20% more grains, a branched ear producing 50% more grains, etc.

Advances in genetic marker-assisted speed breeding, whereby up to six generations can be achieved per year through controlled environment and Light Emitting Diode (LED) technology are enabling more rapid translation of genetic discovery into elite lines.

Remote sensing

There are many new capabilities being developed to assist the farmer and agronomist to manage crops more effectively, many of which are satellite based.

Monitoring of crop health through normalised difference vegetation index (NDVI) measurements, biomass measurements, Green Area Index, crop growth rate, plant stress are all operational and enable farmers/agronomists to target their time more effectively by targeting the inspection of problem areas of paddocks rather than general field walking.

Hyperspectral, pre-symptomatic disease signatures are currently being developed in Controlled Environment conditions by Hummingbird Technologies.

Ground Penetration Radar is now available from satellites and has the capability of penetrating soils up to 1m. This technology has the capability of detecting compaction in subsoils, as well as soil moisture for irrigation scheduling purposes.

Another form of remote sensing; Synthetic Aperture Radar, is an active wavelength which has the potential to penetrate cloud and can also deliver information in the dark.

Field based spore sensors that can be primed to detect the DNA of multiple diseases from the surrounding air are also being developed and would be another key feature in the early detection and intervention of disease ingression. Portable LAMP assay kits are now becoming available whereby growers can take leaf samples and look for the presence of pathogen DNA on recently emerged leaves.

Another approach is a 3D printed spore trap being developed by the University of Manchester

and Sony. A mimic leaf is embedded with sensors that look for the presence of disease enzymes that are used to penetrate the vascular system of the plant and wreak havoc, or pressure sensors to detect the appressorium (pegs) that some diseases; such as rust, use to enter the leaf surface.

Soil health and nutrition

Volatile Organic Compounds (VOCs) are the basis of a new infield technology being developed by PES technologies. The small detector, about the size of a matchbox, is filled with soil and the VOCs that are detected give an indication of the key indicators of soil health.

Variable rate N capabilities are now commonplace with the more progressive farmers.

The age-old debate as to whether to put more or less N on the poorer parts of the crop rages on. A new product from Hummingbird technologies enables growers to test the option of inversing the approach to N at the click of a box. In practical terms, if extra N applied on the lower biomass areas of the crop hasn't produced a positive effect, then less will be applied on the second split, thereby optimising gross margins.

More knowledge is being developed regarding optimum nutritional thresholds during the key stages of crop development. Tissue and grain testing are becoming a more reliable method to test nutrient levels compared to soil testing.

Infield soil sensors are starting to make an appearance. The Terralytic soil probe has 26 sensors and measures soil moisture, salinity, and N, phosphorus (P) and potassium (K) at three different depths, as well as aeration, respiration, air temperature, light, and humidity

The Terramap, which is a small measuring device fitted to an all-terrain vehicle (ATV), measures four naturally emitted isotopes - Caesium-137 (Cs), Uranium-238 (U), Potassium-40 (K) and Thorium-232 (Th). There are approximately 800 reference points per hectare. In comparison, grid sampling map layers have only a single data point per hectare. Strategic soil samples are taken from each paddock and then the scan data and soil sample results are combined and processed to produce up to 21 high-definition soil property layers; P, K, magnesium (Mg), pH and % of clay, sand, silt, calcium, sodium, manganese, boron, copper, molybdenum, iron, zinc, sulphur, organic matter (OM), salinity (CEC) and plant available water are all delivered.

Fungicides, immune enhancers and semiochemicals

After a long time, two new fungicides have arrived on the UK market this season. The first is Revysol® (mefentrifluconazole), a new type of triazole, an isopropanol-Azole, which has been a top performer in AFD trials this year. The second is awaiting imminent approval, InatreqTM from Corteva which is based on a fermentation product of a soil borne Streptomyces bacteria. This has a very similar mode of action as the strobilurins; it acts on complex 3 of the mitochondria.

Plant immune enhancers have been introduced into the market, but their use in terms of timing, dose and frequency is still to be determined. They are based on both systemic acquired resistance and induced systemic resistance. They work by stimulating the salicylic and jasmonic acid pathways. If successful in their development, they could be an important part of a resistance management program

Semiochemical technologies are also currently being developed. An example is; jasmonic acid which naturally repels insects and tricks insects into believing the host is decaying and under attack, and therefore, the plant would not make a viable host.

Others disrupt the mating cycle of insects by confusing the male insect so that it is unable to find a female to mate with. This reduces pest populations.

Attractants can also be used to lure insects into traps containing insecticides. These can be used in conjunction with evolving 'smart trap' technologies whereby insect species are identified and counted, enabling more effective insect control management strategies.

Alternatives to herbicides

The future of glyphosate still hangs in the balance following the current approval period which ends in 2022. Various other techniques are being investigated, for example; the use of pelargonic acid, laser weeding and electronic weeding.

Hight voltage weeding, while very effective and quick in the resulting kill, still must overcome the practical difficulties of generating enough tractor mounted voltage to optimise width and speed of travel.

Laser weeding, whether by robots or boom mounted is more appropriate for wide-row horticulture crops rather than broadacre commodity crops.

Pelargonic acid as a standalone product is not as active on weeds as glyphosate but can considerably enhance the effect of low rates of glyphosate. It has a high application rate of 20-30L/ha which has implications for application and storage

Robotics

There is a lot of activity in this area, but most of the technologies are going to be more suited to horticulture/top fruit crops rather than broadacre commodity crops. Fruit sizing, colour detection and picking are all being developed as well as laser weeding.

The Small Robot Company is developing a partnership of robots – one detects, the other implements. They have a philosophy of 'per plant' establishment and management which they believe will replace conventional methods.

Big data

Finally, 'big data' is a direct consequence of the Internet of Things in agriculture. I don't think we have yet seen the full extent of the advantages of the use of 'big data'. A new UK government funded Agritech Centre, Agrimetrics is developing new services for farming that utilise 'big data'.

Data, at a global level, is on an exponential rate of use, and has increased from 30-40 zettabytes from 2019 to 2020 (1 Zb = 1 trillion gigabytes).

Omnia, a GIS service on offer from Hutchinsons can analyse multi- layers of crop information to give more insight into the output potential of a specific paddock. Yield data from combines, soil sampling, etc. can be compared across many seasons and variable rate applications adjusted accordingly.

Useful references

Regulation (EC) 1107/2009 on the Placing of Plant Protection Products on the Market,

http://www.europarl.europa.eu/RegData/etudes/STUD/2018/615668/EPRS_STU(2018)615668_EN.pdf

European Commission, Communication from the Commission to the Council and the European Parliament - Community strategy for endocrine disrupters - A range of substances suspected of interfering with the hormone systems of humans and wildlife, COM (1999)706 final, 1999. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:51999DC0706

Registering a Pesticide: http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/pesticidesregistration/ ; registering-a-pesticide.htm

Pesticides Usage Survey: https://secure.fera.defra.gov.uk/pusstats/surveys/

Fungicide resistance action group https://ahdb.org.uk/frag

Insecticide resistance action group https://www.irac-online.org/

Weed resistance action group https://ahdb.org.uk/wrag

Yield Plateau – report commissioned by AHDB https://ahdb.org.uk/Tags/Yield%20Plateau

Yield enhancement network (YEN), connects agricultural organisations and farmers who are striving to improve crop yields: https://www.yen.adas.co.uk/

AHDB Fungicide Performance, independent information on the efficacy of fungicides against key diseases in wheat, barley and oilseed rape: https://ahdb.org.uk › fungicide-performance

Tissue derived optimum nutrient thresholds for wheat: https://www.lancrop.com/

Teralytic Wireless NPK soil probe and an analytics platform: https://teralytic.com/

Terramap – passive, gamma-ray detection technology providing high-definition mapping of all common nutrient properties: https://www.omniaprecision.co.uk/terramap/

Omnia Precision: https://www.omniaprecision.co.uk/

Small Robot Company: https://www.smallrobotcompany.com/meet-the-robots#weed-killing

Hummingbird Technologies, crop data analytics using satellites, fixed wing and drones: https://hummingbirdtech.com/

Electronic weeding: https://zasso.com/

Agrimetrics, provides data, tools and services to agrifood businesses: https://agrimetrics.co.uk/

Contact details

Keith Norman,
Independent Agritech Consultant,
keith@keithnorman.com
@KeithNorman_Ag

Return to contents