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Consider…

- *"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology".*

Carl Sagan

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Philosophy

A person who has food has many problems.

A person who has no food has only one.

Chinese proverb

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Reality

- The World Bank estimates that cereal production needs to increase by 50% by 2030 to meet demand.

- Prof John Beddington "We need 50% more production ….on **less land**, with **less water**, using **less energy**, **less fertiliser** and **fewer pesticides**...by 2030"

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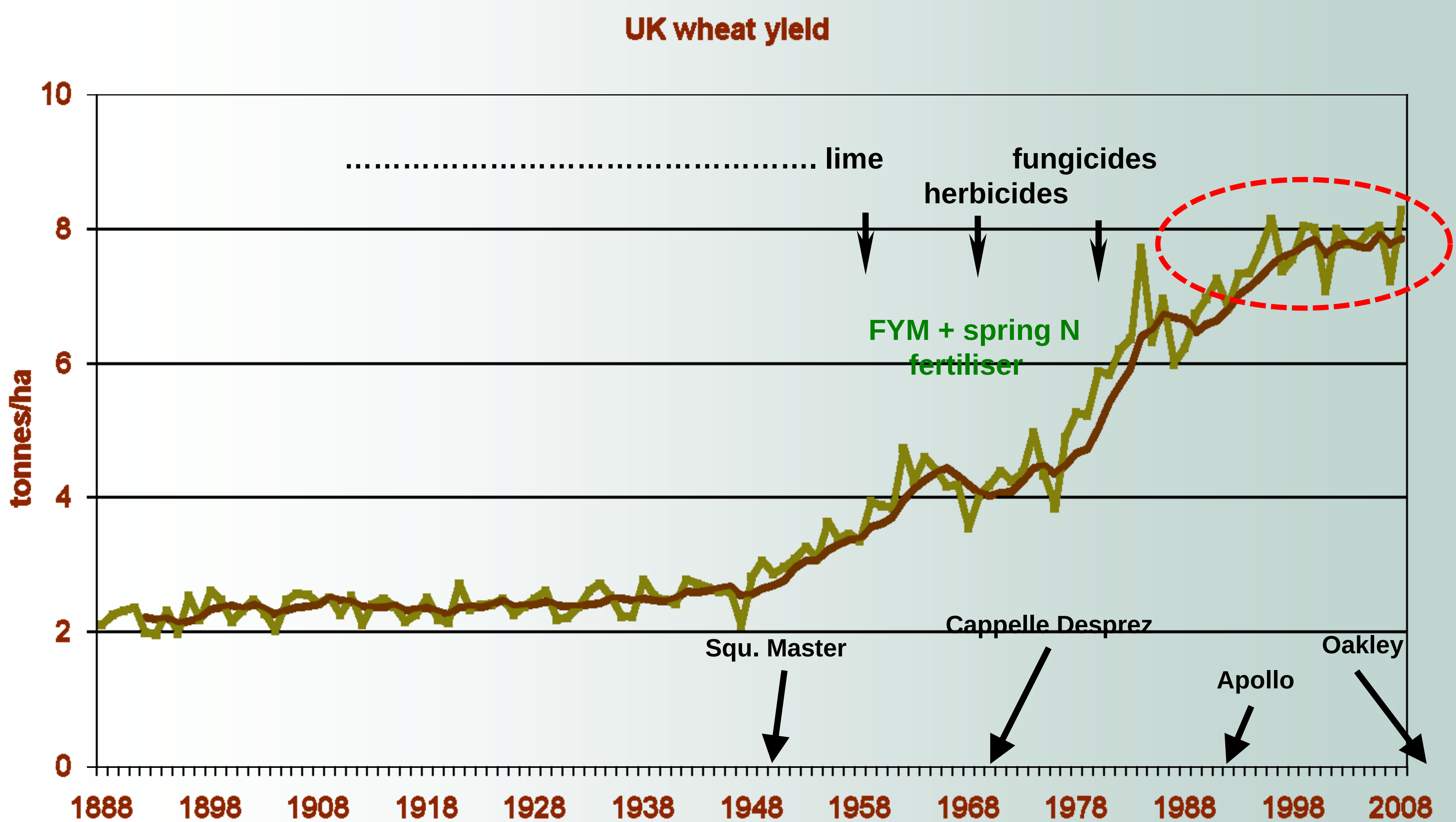
How to increase yields...

Can increase yield in 2 ways:

- Increase the attainable yield (reduce losses due to pests, diseases and abiotic stresses.

- Increase the potential yield of the crop.



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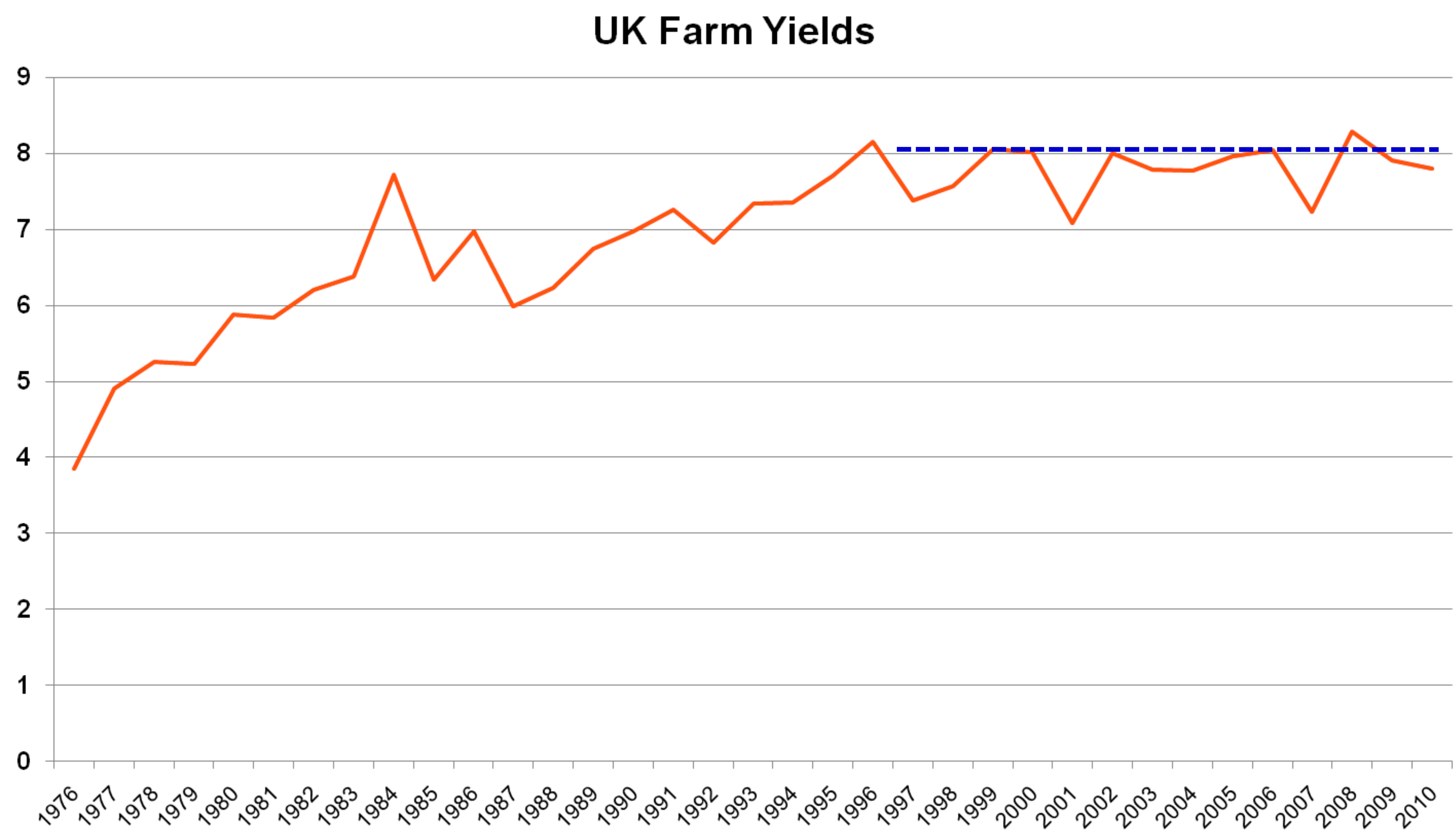

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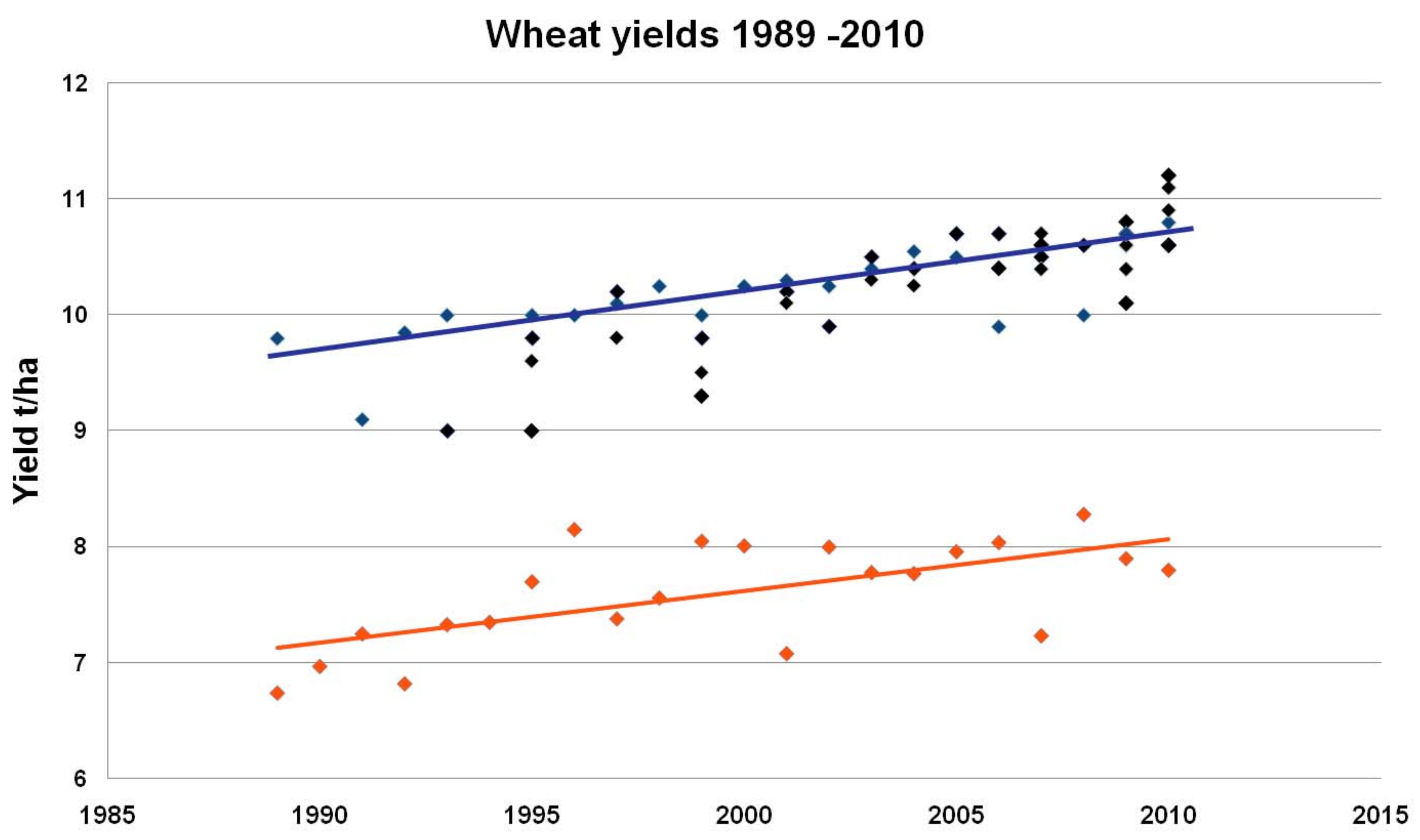

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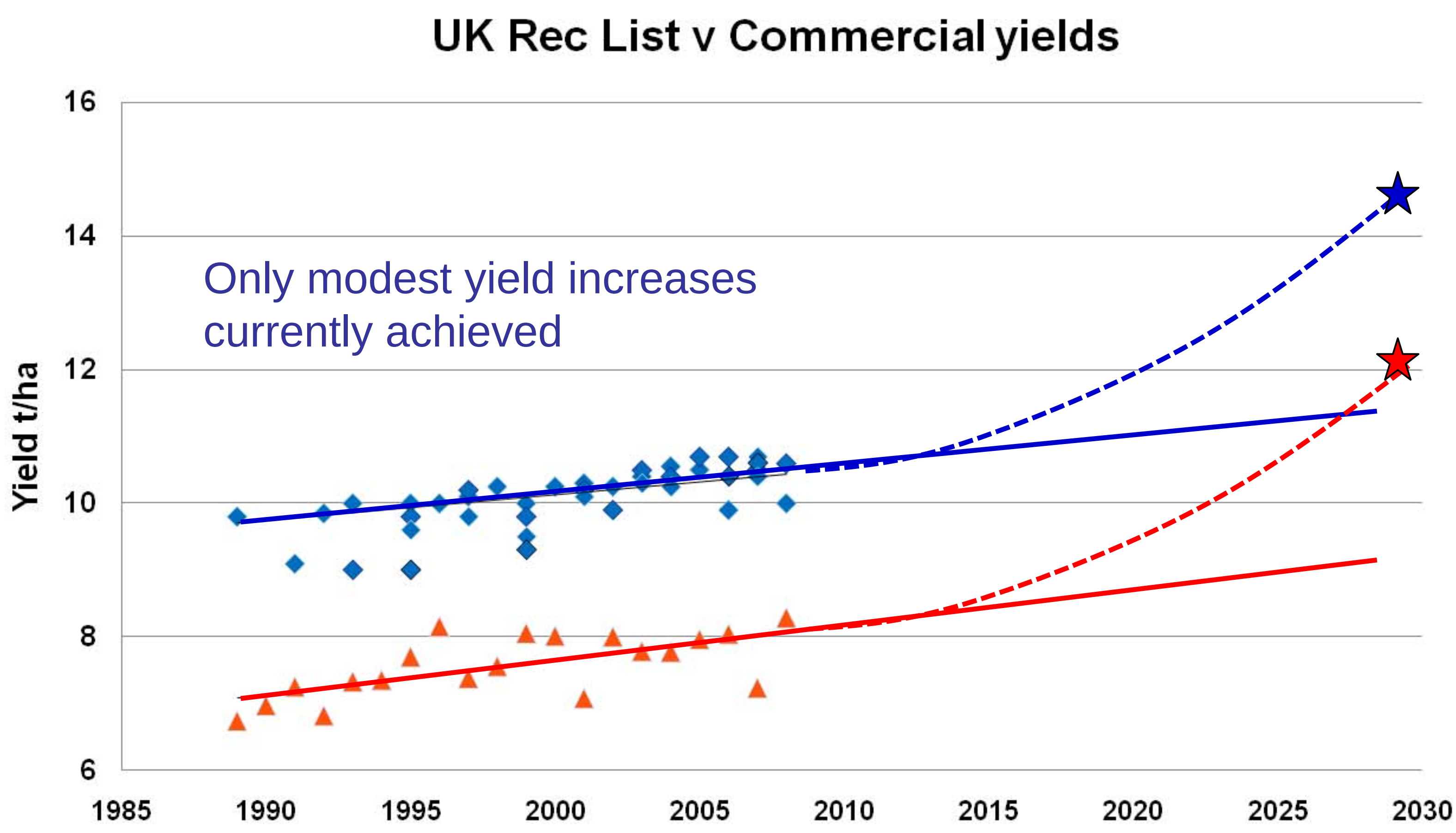
What is achievable by 2030?



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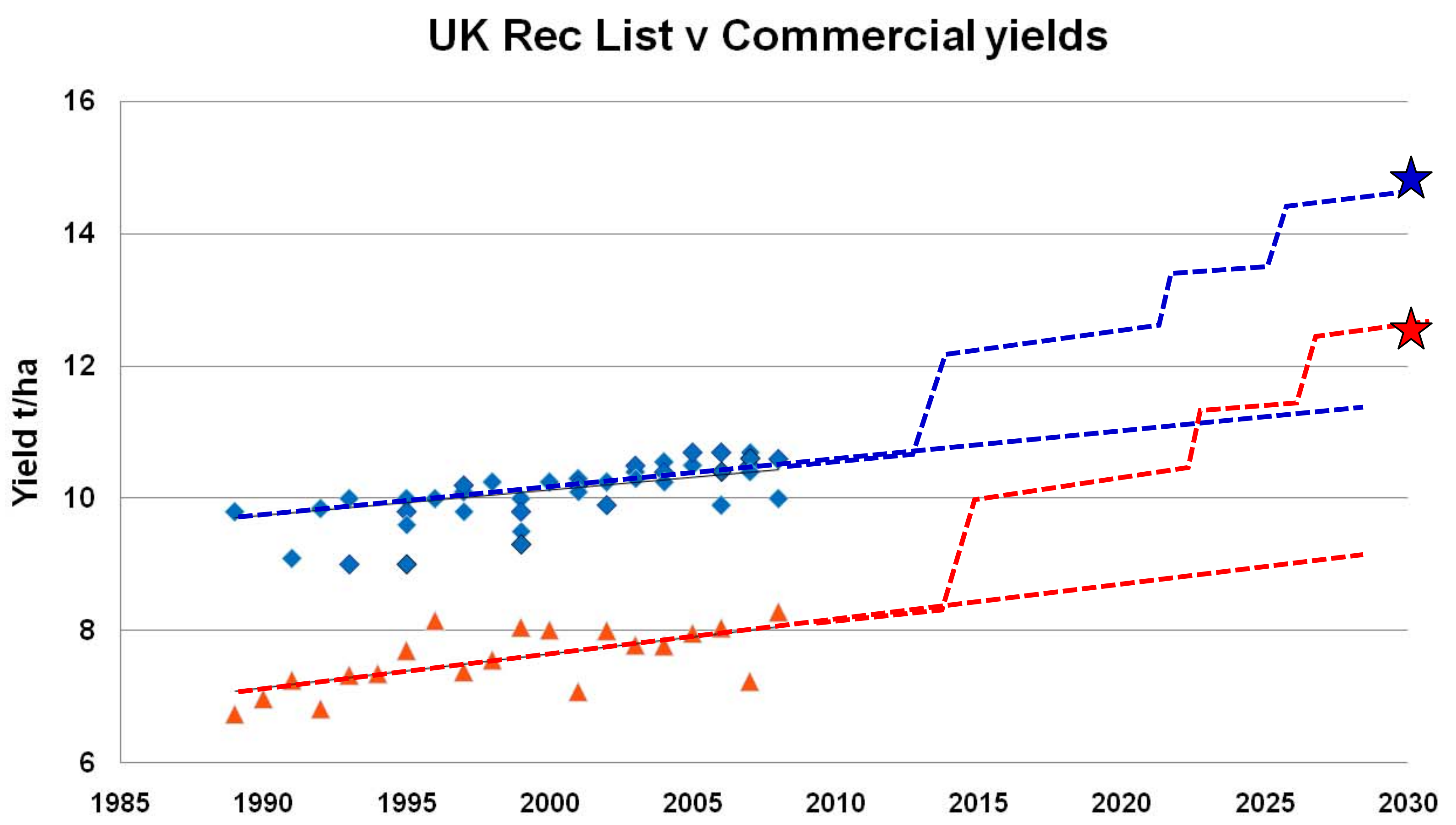
Step changes needed to meet targets



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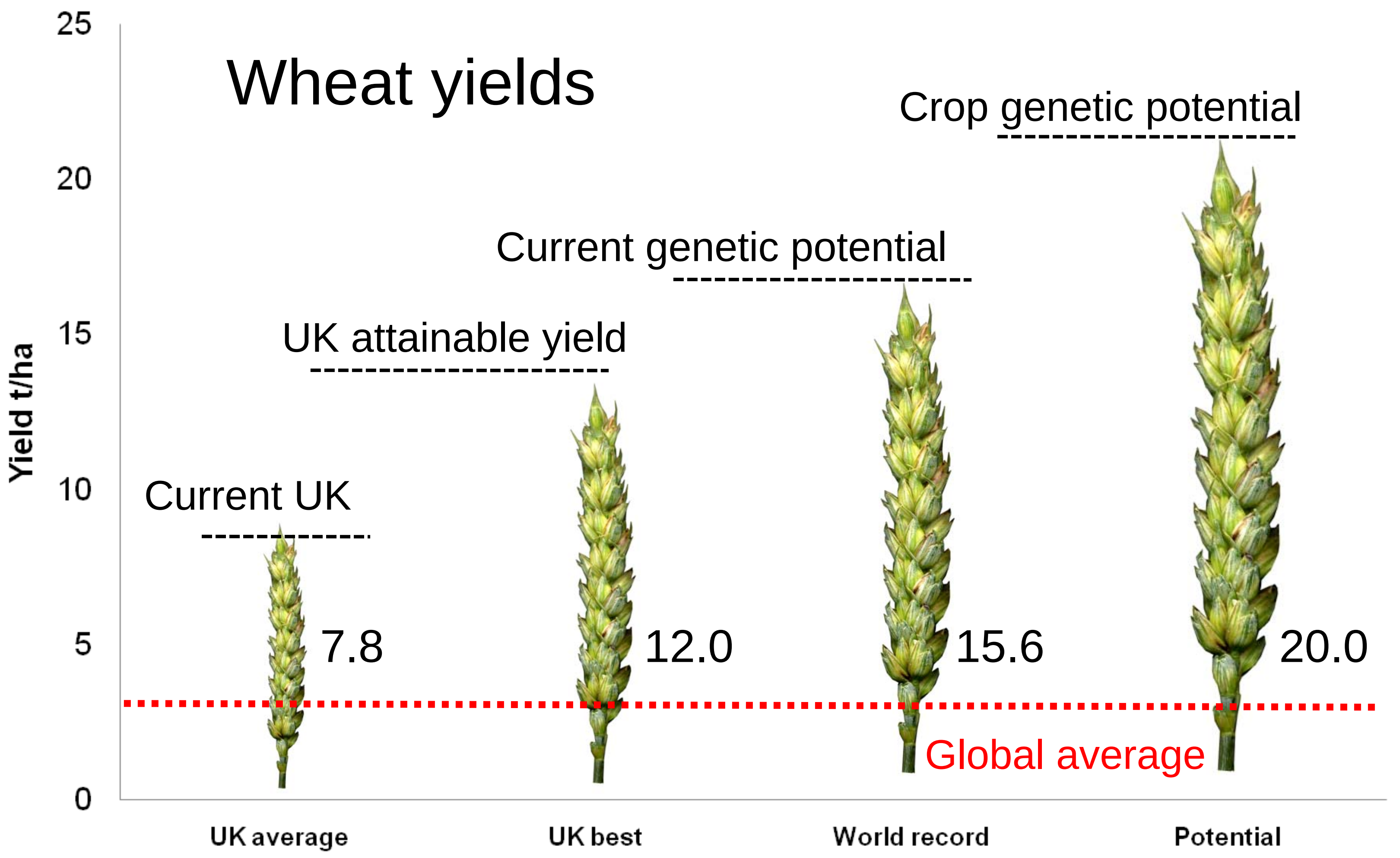

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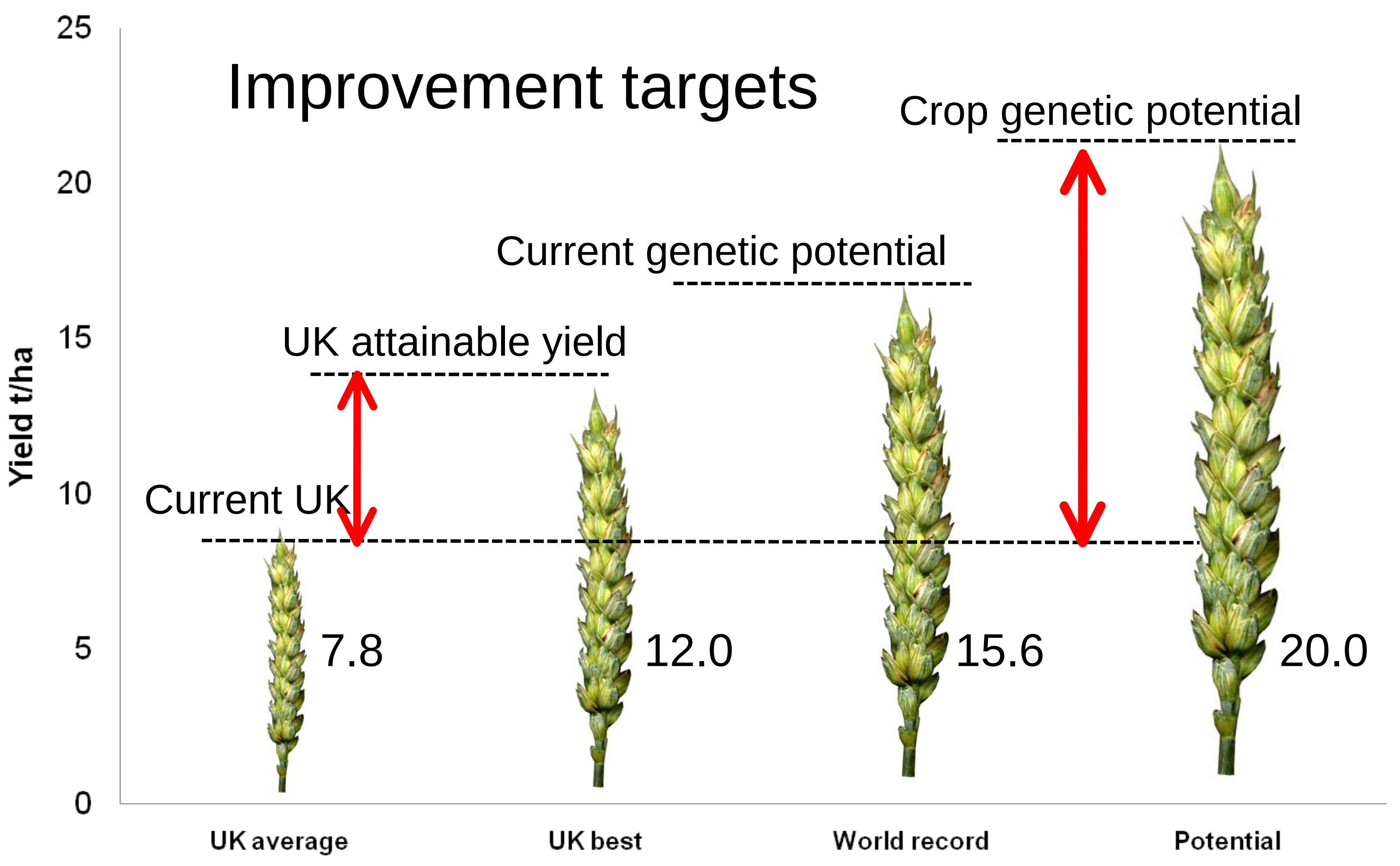

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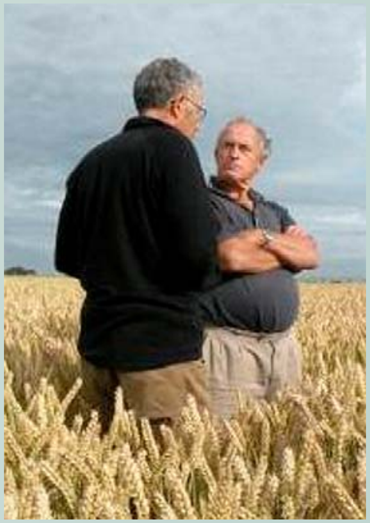
12 tonne wheat

- Genetic potential already exists **.
- Optimise inputs - new pesticides, host-defence compounds, chemically-induced host physiology changes.
- Delay senescence - Increase nutrient and water utilisation.
- Seed treatments to protect against pests and diseases.

**Current world record wheat yield is 15.6 t/ha (NZ, high radiation levels, high N use, no water deficit). New Zealand farmer Mike Solari growing Einstein.



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Increase attainable yield

- Optimising inputs, thresholds, decision support systems, precision farming, new chemistry.

(Some conflict with bigger farms, less manpower, more risk-averse management strategies.)

UK or European perspective –
Not going to deliver enough and not in time.

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Solutions…attainable yield

- Short-term (< 8 years):
- New approaches to crop management.
- New pesticides that directly affect crop physiology.
- Better fungicide programmes, disease reduction.
- Improved input management.
- Seed treatments to protect against pests and diseases.

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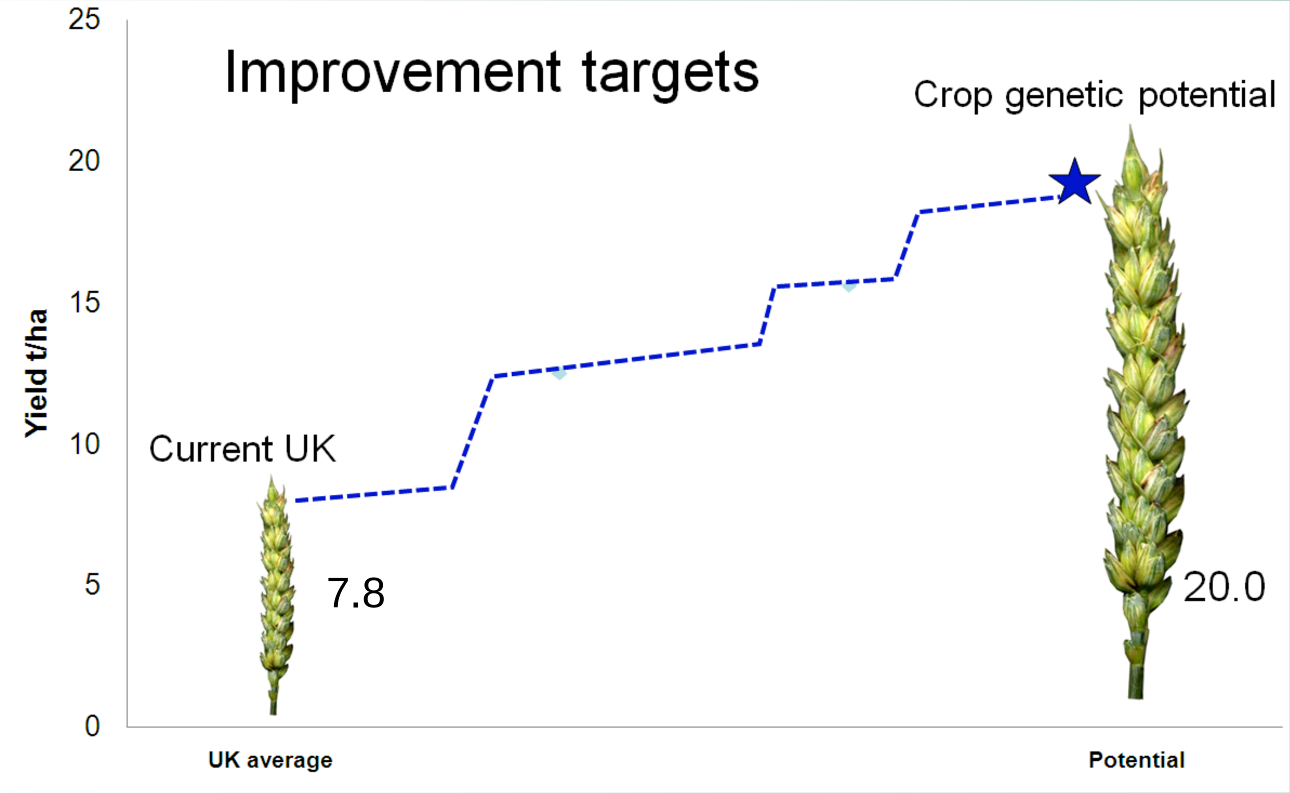
Increase Potential Yield

- Only way to deliver step-change agricultural improvement.



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20 tonne wheat?

Massive intervention in breeding to give:

- Earlier stem extension, early canopy closure,
- Better disease resistance,
- Increase nutrient and water utilisation,
- Delay senescence,
- Increased radiation use efficiency,
- Modify wheat to C4 metabolism - boost the efficiency of photosynthesis.

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Solutions…

Medium-term (<15 years):

- Breeding and Genetic Improvement.
- New varieties of crops that are resistant to disease, drought, salinity, heat.

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Solutions…

Longer-term...speculative (15+ years) :

- The development of nitrogen fixing cereals.
- Perennial cereal crops.
- Increased photosynthetic efficiency (C4 wheat)
- Modified crop development / senescence.
- Increase nutrient and water utilisation,
- Increased radiation use efficiency.

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Tools…

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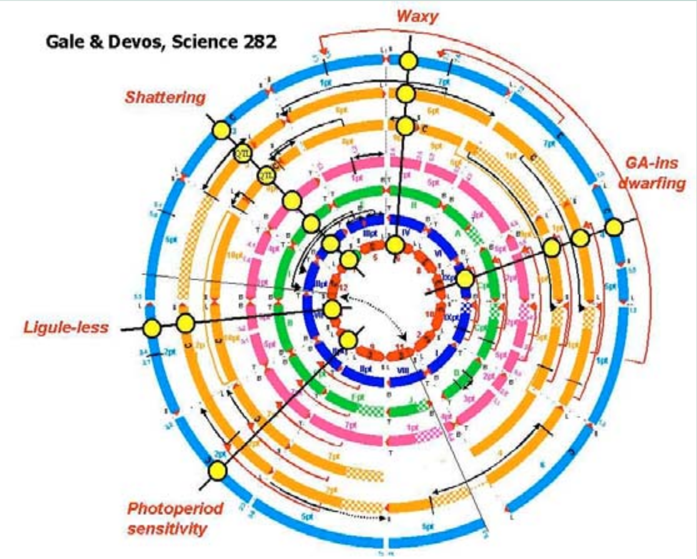
Genomics…

Complete genome sequences of crop plants.

- Genes or combinations of genes affecting crop production can be identified using genomics.
- In genetic improvement strategies these genes can be targeted in breeding programmes or they can be transferred into crops by GM.



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Scientific breakthrough will increase wheat yields

» British researchers map wheat genome

» Plant breeders to develop new varieties

By William Surman

A TEAM of British researchers has cracked one of the toughest genetic codes of any plant with the first mapping of a wheat genome – a genome five times more complex than its human equivalent.

Plant experts have described the breakthrough, which reveals 95 per cent of all wheat genes, as 'a major scientific discovery' which will help farmers across the world increase wheat yields to meet growing global demand for food.

Prof Michael Bevan from the John Innes Centre, the UK's centre of excellence in plant science, said the discovery held the key to genetic improvements, such as drought or salt resistance and improved crop quality, to allow a significant boost to production in the UK and elsewhere.

Genome sequences of most other major crops, such as rice or maize, are already known and as a result their yields outstrip demand, whereas wheat yields have stagnated since 1990. PICTURE: BBSRC

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Farmers Guardian August 2010

Biotech Crops (GM)

P

- Novel genes are introduced, either individually or in small groups, into a crop plant. The genes may either be from the same species (cisgenics) or from another species (transgenics).
- GM-methods are now used widely as a routine tool.
- In the USA, Argentina, Brazil, India and Canada, GM crops are grown widely (Currently 135 million ha)
- In Europe and Africa they are largely absent.

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Improved photosynthesis ↑P

Modification of photosynthetic efficiency could result in massive yield increases.

One approach to this involves attempts to introduce a C4 photosynthetic pathway into plants *as an alternative to the normal* C3 pathway.

(C4 photosynthesis is found in drought-tolerant grasses such as maize and sorghum, but not in wheat and rice).

Why not select C4 plants that are adapted to temperate climates – easier?

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Reduce abiotic stress

↑A

Abiotic stress describes the impact of non-living factors such as drought, salinity, heat.

- Increasing water uptake from soils
- Phenotyping of root characteristics
- Heat tolerant varieties
- Host defence triggers (chemical or genetic)

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Crop protection products

A

- Crop protection chemicals are used widely to protect against weeds, pests and diseases.
- These compounds are the mainstay of global crop protection

- New chemistry resembles chemicals present in plants that activate natural resistance mechanisms.
- Because they do not target pests and pathogens directly, they could have environmental advantages

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Precision

A

- Achieving consistent cereal yields that exceed 70% of the yield potential barrier depends on sophisticated management of soil and water resources and applied inputs.

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Non-host resistance

A

The holy grail of plant breeders.

Most plant species are completely resistant to the pathogens that are specialised to infect other plants.

Rice is resistant to cereal rusts, and tobacco is resistant to potato late blight. Understanding the molecular basis for NHR could enable more durable resistance to be engineered into crops.

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Gene silencing

A

- Switching on or off the plants own genes.
(can only be done with GM technologies). <u>No new genes</u>

- "Vaccination" well understood by general public – Introducing virus resistance to plants via gene silencing is done by inserting a small fragment of a virus into a plant. When the plant is actually exposed to the virus it has a ready defence mechanism primed to destroy the virus.

We even use 'live' viruses
On our children – MMR.

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BYDV infected plants

Gene silenced -
Immune to BYDV

BYDV affected

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Apomixis

↑P

- Heterosis (hybrid vigour) for inbreeding species (that is, species that usually self-pollinate, such as rice and wheat) can offer 20% to over 50% yield increases,
- Next step would be apomixis, where plants produce seed without the need for fertilization. This allows hybrid vigour to be fixed.

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Need new language

- We need terms that the general public are comfortable with (may not understand), such as ‘vaccination’ and ‘immunisation’ rather than ‘genetic modification’ or ‘gene silencing’

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GM or not GM?

X

= Transgenic

Daily Mail

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GM or not GM?

+ virus RNA = Immunisation

+ virus RNA = Immunisation

(Vaccine)

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Conclusions

- Achieving these scientific advances is possible.
- Much of the technology already exists.
- <u>Present levels of investment in these specific research areas are not adequate.</u>
- Without change in attitudes to GM - the most likely scenario for yield potential of the major cereal crops is one of <u>small, incremental increases during the next three decades.</u>
- Even these modest improvements will require considerable research investment.

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