ROTHAMSTED RESEARCH

GM Camelina Questions and Answers

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Key Points

Rothamsted Research successfully applied to Defra to conduct a field trial of a GM Camelina plants that have been engineered to produce omega-3 fish oils and the pigment astaxanthin that may provide health, environmental and economic benefits.

There is a pressing need to find new and sustainable sources of healthy omega-3 fish oils for the fish feed industry to reduce the burden on marine fish oil stocks.
Scientists at Rothamsted Research have been working on a solution to this crucial environmental issue over the last 15 years.

The proposed experiment is publicly funded by the Biotechnology and Biological Sciences Research Council (BBSRC), who is the main funder of biological/food research in the UK.

Key Facts:

- Moderate consumption of at least (250mg/day) of omega-3 oils, specifically long chain polyunsaturated fatty acids (omega-3 LC-PUFAs) commonly known as omega-3 fish oils through the intake of oily fish, e.g. salmon and mackerel, has been linked to improved cardiovascular health and cognitive development.
- Fish do not themselves produce these oils but instead accumulate them through their diet; the main producers of omega-3 LC PUFA are marine microalgae.
- In 2013 51% of all fish directly consumed by humans worldwide was produced by fish farming (known as aquaculture), with this figure set to rise in the next few years (http://www.seafish.org/industry-support/aquaculture).
- Currently the fish farming industry (i.e. aquaculture) is providing as much fish oil for human consumption as it consumes through fish feed. The aquaculture industry is growing year on year in order to provide high quality protein for human consumption.
- Astaxanthin is a carotenoid pigment that has antioxidant properties and is used as a feed additive in fish farming. It is the pigment that gives salmon its characteristic pink colour. Astaxanthin is found in some marine organisms at the base of the food-web such as algae and krill.
- The application to Defra concerned a proposed controlled experiment publicly funded to test the performance of transgenic Camelina plants in the field.
- We have successfully developed Camelina plants with high content of omega-3 fish oils in the laboratory/glasshouse and have tested them previously in the field.
- Currently we have developed Camelina plants that have enhanced levels of omega-3 fish oils and also the astaxanthin pigment. Rothamsted scientists are testing this under ‘real-life’ conditions in the field to see if this can provide a scalable solution for aquaculture.

- The technology we have developed has a considerable advantage in that it produces the right profile of omega-3 LC-PUFAs in significant quantities as well as the important aquafeed component astaxanthin.
- This technology may help reduce the environmental and economic costs for aquaculture, help promote human health and could have wider ecological benefits by protecting marine habitats through making a terrestrial source of this essential oil utilising existing farming practice and machinery.
- The crop that will be harvested from the field in this experiment will not be used for feeding fish but should the trial be successful fish feeding experiments may be considered in the future.
- GM is just one of many techniques we use at Rothamsted Research to address the serious challenges we face to secure an environmentally sustainable supply of food. The GM trial will be less than 1% of our experiments in the field this year.

Questions & Answers

GENERAL

1. **Why are omega-3 long chain polyunsaturated fatty acids (LC-PUFAs) important?**

   Omega-3 long chain polyunsaturated fatty acids (LC-PUFAs) are important for human health and nutrition.

   Strong evidence shows that consumption of fish and in particular oily fish lowers the risk of death (36 per cent reduction) caused by coronary heart diseases (CHD) (Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption 2011 available at: www.fao.org/docrep/014/ba0136e/ba0136e00.pdf).

   National and International guidelines have converged on consistent recommendations for the general population to consume at least 250mg/day of long chain Omega-3 LC-PUFAs or at least 2 servings/week of oily fish (J Am Coll Cardiol 2011; 58:2047-67) for optimal protection against CHD.

   The omega-3 LC-PUFAs that are beneficial for health are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). They modulate both metabolic and immune processes and confer health benefits in areas of CHD and neurodevelopment (Nutrition Reviews Vol.71(10):692-707).

2. **What is the source of EPA and DHA omega-3 LC-PUFAs and astaxanthin?**
   As with humans, most fish obtain EPA and DHA through their diets. Thus, fish oils aren't actually made by fish, but rather they are synthesised by marine microbes, which form the base of aquatic food webs.

   Farmed marine fish need to be provided with the dietary EPA and DHA fatty acids through their feed in order to be comparable with and as healthy as their wild counterparts.

   For feed purposes of farmed fish, fish oil is in practice the only economically viable source of these essential fats, and around 80 per cent of all fish oil produced in 2011 was consumed by the fish-farming sector (Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption 2011 available at: www.fao.org/docrep/014/ba0136e/ba0136e00.pdf).
   As the human population increases and the oceans and fish stocks become increasingly limited, fish farming (aquaculture) is becoming a major source of fish for human consumption. The UK aquaculture industry is a significant sector. EU aquaculture is valued at €3.2 billion and

accounts for one-quarter of all EU production of fish, molluscs and crustaceans. According to the Centre for Environment, Fisheries and Aquaculture Science (Cefas), in the UK the total value of aquaculture finfish production in 2010 was £484 million (http://www.cefas.defra.gov.uk/publications/finfishnews/ffn13.pdf). Aquaculture is an excellent means by which high-quality protein for human nutrition is produced (more efficient than terrestrial farming) but is heavily dependent on marine-derived inputs (fish oil and fish meal).

Fish oil and meal is usually sourced through the harvesting of "feed-grade" species, which would not normally be suitable for direct human consumption. However, the so-called reduction fisheries are at their sustainable limits and so fish oil and meal are finite resources that cannot increase as demand increases.

There is considerable awareness and much effort in the aquaculture sector to make current fish feed production practices more sustainable, with less negative impact on the aquatic food web. This is why another source of omega-3 LC-PUFAs is required.

Astaxanthin is a ketocarotenoid pigment which is abundant in the marine environment. It is made by a few marine microalgae and also small crustacea such as krill, giving them their distinctive pink colour. Astaxanthin is included in the feeds of farmed fish such as salmon, to give them their characteristic pink colour.

Astaxanthin for use in aquaculture can be produced chemically or can be sourced from the marine organisms which are the primary producers. However, such biological sources put additional pressure on marine ecosystems.

3. **Why do you need to do this experiment?**

We have successfully developed Camelina plants with high content of novel healthy fish oils in the laboratory/glasshouse http://www.rothamsted.ac.uk/news/crop-plants-green-factories-fish-oils and we tested how they performed in the field previously (2014 and 2015). The results from the 2014 field trial have been already published (Usher et al. 2015).

Currently, we have developed Camelina plants with elevated content of omega-3 fish oils. We have also further engineered these new Camelina plants to produce astaxanthin.
We wish to test these new plants under 'real-life' conditions in the field to see if they can provide a viable solution for fish feed production that may be proven in the long run to be beneficial for health, the environment and society as whole.

4. **Why do you have to use GM: is there another way?**

The key LC–PUFAs that are beneficial to health are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).
Current plant sources of omega-3 PUFAs, e.g. Flax seed, do not produce EPA and DHA; instead they produce shorter chain omega-3 fatty acids such as alpha-linolenic acid (ALA). ALA does not confer the health-beneficial properties associated with EPA and DHA, despite also being an omega-3 fatty acid. Not all omega-3 fatty acids are equivalent.
No higher plants are known to accumulate EPA or DHA.
Regarding astaxanthin, only very few plants accumulate this pigment, usually in their flowers. This includes the Adonis plant from which genes were copied to make astaxanthin in Camelina.

5. **Can we not just get algae to produce the omega-3 and astaxanthin?**

It is possible, but it would require vast amounts of algae, be very expensive and would require a quantum leap in existing technology.
However, here at Rothamsted Research, we explore all possibilities for the development of sustainable sources of EPA and DHA omega-3 and we carry out research in algae and diatoms.

Although we have recently demonstrated significant progress in this area, we are still at earlier stages in this work than with our work in Camelina plants. Producing these oils in Camelina would only require the use of standard, established farming practices and machinery.

6. **What is the nature of the genetic modifications you have made?**

Synthetic gene sequences encoding enzymes involved in the biosynthesis of omega-3 LC-PUFAs and astaxanthin have been optimised so that they can be functional in Camelina plants. These synthetic sequences are based on the sequence of genes found in photosynthetic marine organisms, which are part of the phytoplankton, and other lower eukaryote species, which accumulate EPA and DHA, such as mosses and oomycetes. In the case of astaxanthin the synthetic sequences were based on the sequence of genes found in other higher plants.
We have produced three varieties of plants, one that seven synthetic genes have been introduced into the plant and they make EPA and DHA omega-3 LC-PUFAs, one that has three synthetic genes and makes astaxanthin and one that has combined the genes to make EPA, DHA and astaxanthin.

The reason why we needed to introduce this number of synthetic genes is that the synthesis of omega-3 LC-PUFAs and astaxanthin requires multi-step processes. In order to achieve maximum production of these oils and the pigment in the seed of Camelina plants we had to help the internal biosynthetic machinery of the plant to shift from ALA towards the production of EPA and DHA and also produce the pigment.

All the genes producing LC-PUFAs and astaxanthin are expressed (i.e. function) only in the seeds of the Camelina plant and are most active during the mid-stage of seed development. Gene expression has not been observed in any other vegetative tissue during the life cycle of the plant.

All plants expressing the inserted genes look exactly the same as the control plants in the glasshouse. The inheritance of the inserted genes over five generations follows normal rules of Mendelian genetics. No difference has been observed in seed set, seed size or germination. No difference was observed in fertility. Vegetative performance of the transgenic plants was unaltered.

7. **How important is this research?**

This research is very important at three levels: a) scientifically, as the delivery of a plant that produces seeds with the above characteristics depends on employing the most complex genetic and metabolic engineering approaches used in plants to date; b) economically, because we are close to delivering plants able to produce the seeds enriched in omega-3 LC-PUFAs to the farmers and the end users; finally and most importantly c) it offers societal benefits, because of the impact that this research could have both to human health and the environment.

8. **How have you communicated this research and the possibility of a field trial?**

   We have been working on this area of research for the last almost 20 years and information has been available on our website over this period, for example as a factsheet produced in 2011, and through press releases regarding relevant publications.
   We have also spoken to the public and scientific audiences, as well as the press, on many occasions about this work. For example the former Director of Rothamsted Research spoke at the Cereals 2012 event, as reported in Farmers Weekly http://www.fwi.co.uk/articles/15/06/2012/133442/39gm-oilseed-rape-could-cut-healthcare-bill39.htm

   Since 2014, when we initiated the first field trials for this work we communicated this work and engaged in dialogue extensively.

9. **Will the public be consulted?**

   As part of the Defra process, there is a period of a public consultation. People can make representations to Defra on any environmental risks that it is thought might be posed, by the field trial. These will be considered by ACRE.

   ACRE is a statutory advisory committee appointed under section 124 of the Environmental Protection Act 1990 to provide advice to government regarding the release and marketing of genetically modified organisms (www.defra.gov.uk/acre/).

10. **Why is there a need to carry out this research in the UK?**

    This research could benefit UK crop farmers, fish farmers and the environment.
    The UK has world-class plant scientists who should be at the forefront of developing scientific and technological advances that can make agriculture more efficient and sustainable. To promote the UK's competitiveness, investment in biotechnology and therefore ensure long term benefits to the taxpayer.

    The UK aquaculture industry is a significant sector. EU aquaculture is valued at €3.2 billion and accounts for one-quarter of all EU production of fish, molluscs and crustaceans. According to the Centre for Environment, Fisheries and Aquaculture Science (Cefas), the total value of aquaculture finfish production for the food chain in 2010 was £484 million (http://www.cefas.defra.gov.uk/publications/finfishnews/ffn13.pdf).

11. **Are there any fish feeding trials planned with the oil that you may obtain from the plants used for this field experiment?**

    No, there are no fish feeding experiments planned as part of this field trial. The seeds collected from the plants grown at the proposed field trial will be used only for analysis of oil content in the laboratory and not as a source of oil to be used for feeding experiments of salmon. We have, however, other experiments using plants grown in the glasshouses where we use the oil from the seeds for fish feeding experiments.

    As part of this wider programme of research carried out at Rothamsted Research there was an Industrial Partnership Award (IPA) funded mainly by BBSRC, and with BioMar Ltd. contributing 10% of the overall project costs. Professor Johnathan Napier at Rothamsted Research and

Professor Douglas Tocher at the Institute of Aquaculture, University of Stirling collaborated for this project. The aim of this project was to develop a novel sustainable source of omega-3 LC-PUFAs, specifically tailored for the aquaculture industry, through *de novo* production in metabolically engineered terrestrial oilseed crops. The platform crop that was utilised for transgenic oil production was *Camelina sativa* or false flax and the LC-PUFAs oils produced were tested and validated as sources of sustainable omega-3 enriched feeds for the UK salmon industry. For this project, the seeds from Camelina plants that have been grown in the glasshouses were used for the experiments. The feed was given to salmon used for experimental purposes and not to salmon produced for human consumption.

The proposed field trial is part of the overall strategic programme of research carried out at Rothamsted Research and funded by BBSRC.

HEALTH & SAFETY

1. **Will the trial be safe?**

   Rigorous regulations govern the planting of GM crops in the UK. The Government's independent group, ACRE (the Advisory Committee on Releases to the Environment), will be reviewing the risk assessment that has been submitted to Defra as part of the application for permission to conduct the trial.

   At Rothamsted Research we have an internal GM Safety Committee, which thoroughly carries out risk assessments of proposed field trials prior to submission to ACRE and no major safety concern has been raised.

2. **Will anyone inspect the trial?**

   The Genetic Modification Inspectorate, which is part of the UK's Animal and Plant Health Agency will conduct inspections throughout the trial.

3. **Could you give us a brief overview of the process of approval for research using genetically modified organisms (GMOs)?**

   At Rothamsted, like many universities and research institutes around the world, work is taking place using GM plants and microbes for a variety of projects and to address specific scientific questions. Research is conducted in our laboratories, in our glasshouses and in some instances, in the fields of our research farm. For each of these areas where research using GMOs is undertaken, there are a series of relevant regulations that are followed and risk assessments procedures that are carried out.

   Rothamsted Research's activities are compliant with the law and our GM Safety Committee oversees all projects that involve GMOs. There are several key pieces of legislation specifically concerned with the contained use of genetically modified organisms (GMOs). The main piece of legislation, covering both human health and environmental aspects of work in laboratories and glasshouses with genetically modified organisms, is the Genetically Modified Organisms (Contained Use) Regulations 2000, as amended (referred to hereafter as the Contained Use Regulations). In risk assessment of our procedures we follow best practice as specified by the Compendium of
   Guidance http://www.hse.gov.uk/biosafety/gmo/acgm/acgmcomp/index.htm that has been

put in place by the Health and Safety Executive (HSE), in conjunction with the Department for Environment, Food and Rural Affairs (Defra) and the Scottish Government.

Occasionally, a research project requires experimentation using GMOs in the field and for this, approval/permission from Defra is required. The procedure is as follows: We have to carry out a full risk assessment of the project and submit an application to Defra where we describe clearly the aims of our experiment, the type of plant material and the specific genetic modifications that we have carried out. We are also required to make an assessment of the risks to human health and the environment. The application becomes publicly available on the Defra website and our application is then independently assessed by the Advisory Committee on Releases to the Environment (ACRE). During the period that the application is being considered there is also a 48-day public consultation carried out by Defra where any member of the public can comment or ask any relevant question. Once the review of the risk assessment has been carried out, ACRE make their recommendation to Defra who may or may not then grant a consent to conduct an experimental field trial (with specific conditions if appropriate). The trial and the management procedures are regularly inspected and reports made publicly available at www.gm-inspectorate.gov.uk/deliberateRelease/exptreleases.cfm

4. **What security measures will you be taking?**

   Completely surrounding the site will be a 2.4m high chain-link fence (with lockable double gates) to prevent the entry of rabbits and other large mammals including unauthorised humans.

5. **Will you need fences and why?**

   Unfortunately, in the past, GM field trials in the UK have been damaged by people who believe that no GM crops should be planted. Although these GM plants pose no danger to the public, we have felt it necessary to put in place various security measures, including surrounding the trial by a tall fence, to prevent unauthorised access.

   This will be a controlled experiment and we want to ensure that the experiment is conducted with the scientific rigour and high standards expected at Rothamsted Research.
   To do this, we need to ensure that rabbits, dogs, other large animals and people do not wander into the field and interfere with the experiment.

6. **In the US, modified genes have transferred into local wild plants creating 'superweeds', which are resistant to herbicides. Will this happen here?"**

   Some of the Camelina plants that will be used for this experiment contain a gene a gene that confers herbicide resistance. However, this gene has been introduced as a selection marker for laboratory procedures and hence contained use. Should we get permission to carry out the field trial, we will not be using herbicide to control weeds in this experiment. Therefore, the herbicide tolerance gene present in some of the tested plants will have no functional relevance.

7. **What about cross-pollination?**

   It is highly unlikely that these modified genes will get into other crops.

It has been reported that *Camelina sativa* can intercross with other members of the Camelina genus, in particular *Camelina microcarpa* and *Camelina alyssum*. However, these weed species are not grown anywhere near where the trial will take place.

Within the larger Camelineae tribe, species such as *Arabidopsis lyrata*, *Capsella bursa pastoris* and *Neslia paniculata* are believed not to cross-hybridise with *C. sativa*, or result in viable seed (Julie-Galau et al., 2013).

No cross-pollination, either natural or forced, has been observed between *C. sativa* and members of the Brassica genus, such as *B. napus*, *B. juncea*, *B. rapa* and *B. nigra*.

In the laboratory, artificial hybridisation between protoplasts (plant cells without cell walls) of *C. sativa* and *B. napus*, *B. carinata* and *B. oleracea* has been reported, but with low success and/or sterile hybrids (http://www.inspection.gc.ca/plants/plants-with-novel-traits/applicants/directive-94-08/biology-documents/camelina-sativa-l-/eng/1330971423348/1330971509470).

Although cross-pollination is highly unlikely, management measures will be in place to further ensure that such events do not occur.

There will be no sexually compatible species grown within 1000m from the boundary of the site and no sexually-compatible wild relatives of *C. sativa* have been found in the vicinity.

Pollen dispersal will be minimised through the placing of wild-type *C. sativa* on the external strip of the experimental plot – this will serve as a pollen-trap for pollen released from the GM *C. sativa*.. In addition, the entire site is contained by two chain-link fences, which also serve as physical barriers to impede foraging bees. A fine mesh net will be used to isolate the crop when it reaches flowering, preventing pollen transmission by insects.

The outer edge of the trial will have at least a 7m barrier of non-GM *C. sativa* to function as a pollen barrier. The machinery for sowing seeds will be filled on the trial area and will be thoroughly cleaned before leaving the trial area. To minimise the possibility of seed loss, the plants will be harvested just prior to full maturity. All straw will be chopped and left on site.

8. **Would any trace of gene transfer affect where farmers can sell their produce?**

The chances of gene transfer affecting farmers if this experiment is conducted are exceptionally low.
See also **7. cross-pollination**

9. **Are you going to test the safety of the omega-3 and astaxanthin enriched oil produced?**

The aim of the proposed trial is to only test the performance of the plant under field conditions and its ability to produce omega-3 fish oils and astaxanthin in the seed, as has been observed in the glasshouse experiments.

ECOLOGY

1. **How is this Camelina better for the environment?**

We hope the experiment will help tell us whether we can use plants to produce a more sustainable source of healthy fish oils.
Substantial efforts are being made internationally by the research community and the aquaculture feed industry to increase the sustainability of fish feed production practices.

2. **Do you foresee any environmental problems from Camelina? For example down the food chain? Or on wild plants?**

   No. *C. sativa* originated in Europe, and was historically grown across South-Eastern Europe and South-Western Asia. It is a native species in many European countries, including the United Kingdom.

   In recent years *C. sativa* has not been widely cultivated as a crop in the UK.

   C. sativa is grown as a crop in Canada and parts of the USA.

3. **What are the effects on biodiversity of this research?**

   This is a small-scale highly controlled experiment over the course of two years. We do not anticipate any effects on biodiversity.

TECHNICAL QUESTIONS

1. **How did you make the GM plants?**

   Synthetic gene sequences encoding enzymes involved in the biosynthesis of omega-3 LC-PUFAs and astaxanthin have been optimised so that they can be functional in Camelina plants. These synthetic sequences are based on the sequence of genes found in photosynthetic marine organisms, which are part of the phytoplankton, and other lower eukaryote species, which accumulate EPA and DHA, such as mosses and oomycetes. In the case of astaxanthin the synthetic sequences were based on the sequence of genes found in other higher plants.

   We have produced three varieties of plants, one that seven synthetic genes have been introduced into the plant and they make EPA and DHA omega-3 LC-PUFAs, one that has three synthetic genes and makes astaxanthin and one that has combined the genes to make EPA, DHA and astaxanthin.

   The reason why we needed to introduce this number of synthetic genes is that the synthesis of omega-3 LC-PUFAs and astaxanthin requires multi-step processes. In order to achieve maximum production of these oils and the pigment in the seed of Camelina plants we had to help the internal biosynthetic machinery of the plant to shift from ALA towards the production of EPA and DHA and also produce the pigment.

   All the genes are expressed i.e. function only in the seeds of the Camelina plant and are maximally active during the mid-stage of seed development.

   To achieve expression of the inserted sequences only in the seed of the Camelina plants we used gene-switches (genetic sequence that is part of other genes) which determine when and where the synthetic gene sequences will give the information to make the useful enzymes for making the oil. The “gene-switches” (also known as promoters) originate from genes in other plants such as *Brassica napus*, Arabidopsis and *Linum usitatissimum* and in one instance from the Cassava vein mosaic virus.

Since we have inserted a number of genes next to each other into the plant, in order to make sure that each gene stops making protein at the correct point we have inserted some genetic "end-signal" sequences in between the genes that facilitate that. In our system these end-signal sequences originate from various organisms including Arabidopsis*, Agrobacterium tumefaciens* and Cauliflower mosaic virus*.*

2. **Can you see any differences between normal plants and the GM ones?**

   All plants expressing the inserted genes look exactly the same as the control plants in the glasshouse. The inheritance of the inserted genes over 5 generations follows normal rules of Mendelian genetics. No difference has been observed in seed set, seed size or germination. No difference was observed in fertility. Vegetative performance of the transgenic plants was unaltered.

   Gene expression has not been observed in any other vegetative tissue during the life cycle of the plant.

3. **Where did the genes come from?**

   All the genes used in order to engineer these Camelina plants are synthetic i.e. they have been custom-made by chemical synthesis based on gene sequences found in algae, diatoms, moss and oomycetes and in the case of astaxanthin genes found in higher plants.

4. **Could the genetic changes end up in other organisms and cause problems?**

   The chances that this could happen are exceptionally low given the scale of this experiment and with the safety measures in place.

5. **Will your experiment be legal?**

   Yes. GM experiments are allowed in Europe as long as the strict regulations to ensure safety are followed. This GM field trial will only proceed if it is authorised by Defra after a careful evaluation of the evidence.

LOGISTICAL QUESTIONS

1. **Where is the trial taking place?**

   The GM field trial, if approved, will take place on the experimental farm at Rothamsted Research in Harpenden, an agricultural research establishment which is primarily publically funded and receives strategic funding from the Biotechnology and Biological Sciences Research Council (BBSRC).

   Rothamsted Research has many experimental plots covering the whole estate, of which this trial forms one very small part. Some of these experimental plots have been running continuously for more than 170 years, helping to shape our knowledge of agriculture and ecology.

These Long Term Experiments, a UK national capability funded by the BBSRC and Lawes Agricultural Trust, are unique and precious. They provide valuable data for current research at Rothamsted Research, as well as being an invaluable UK and international resource.

2. **Will I be able to come and look at it?**

   Yes, it will be possible to see the trial but you will require permission from Rothamsted Research in order to do this.

   The plot is surrounded by a perimeter fence that has been erected to prevent the entry of rabbits, other large mammals, and unauthorised people to ensure the experiment is conducted with the scientific rigour and high standards expected at Rothamsted Research.

3. **How big is it?**

   The area of the proposed trial, including controls and spacing between GM plots will cover ~50mx50m including the pollen barrier.

4. **How long for will the trial be carried out? i.e. How many seasons, how many replicates?**

   The trial will be carried out over a period of two years in the spring/summer seasons of 2016 and 2017. The plants will be sown in April/May and harvested in Aug/Sept.

FINANCE & COMMERCIALISATION QUESTIONS

1. **How much will it cost? Who will be paying for it?**

   Rothamsted Research will fund this trial from the strategic funding that it receives from the Biotechnology and Biological Sciences Research Council (BBSRC).

2. **Isn't this just a waste of taxpayers' money?**

   No. On the contrary. This research has been undertaken for many years in the lab and the glasshouses and in the last two years in the field at Rothamsted Research. The results from the field trial conducted in 2014 were published in 2015 and it was demonstrated that the plants could stably produce omega-3 fish oils in the field. Currently, we have developed plants that have the potential to produce higher levels of omega-3 fish oils as well as the pigment astaxanthin. This experiment will assist in determining whether this technology could provide environmental and financial benefits for the UK economy and the UK taxpayer.

3. **Have you received industry funding for this work?**

   Rothamsted Research does receive some funding from industry and aspects of the development of this technology over the last 15 years have been made in collaboration with industrial partners, but this particular trial is publicly funded.

   Aquaculture and fish feed manufacture are modern progressive industries working together with many research organisations and international networks to explore ways of producing fish oil in an environmentally sustainable manner.

Our overarching philosophy is that we need to work with government policymakers, non-government organisations (NGOs), agribusinesses and farmers if we are to deliver the knowledge, innovation and new practices to increase crop productivity and quality and to develop environmentally sustainable solutions for agriculture.
Working with industry forms a crucial component of this if we are to turn our scientific knowledge into technologies that can benefit farmers, because it is only industrial partners that have the necessary infrastructure to develop and distribute innovative technologies to those who need it.

However, we also recognise that the UK taxpayer is the main funder of our research. We recently carried out a formal public dialogue in order to listen to the views of the public and our stakeholders on our collaborations with industry and to receive their input in developing guiding principles of how we should work with industry.

4. **Who owns the existing patents in this area, and who will own the results of this research?**

   There have been many patents filed over the years covering various aspects of this area of research and various methods producing omega-3 oils from plants. They are owned by a number of organisations.

   Rothamsted Research has filed patents for Camelina to be used for a number of applications. Rothamsted Research will license these under the Institute's terms and conditions so as to recover investment for the UK taxpayer.

5. **Are there any potential economic returns from this research, and who will gain from it?**

   Rothamsted Research holds Intellectual Property rights over the methodology that has been developed to make these plants. Potentially this technology could be licensed to one or more companies under Rothamsted Research terms and conditions to produce/supply seed and produce oil from the seed. Given the size of the market for these oils, the potential economic return is considerable.

6. **How will you ensure this doesn't just line the pockets of industry but reaches those who will benefit from the technology but may not be able to afford it?**

   When licensing our technology to commercial producers, our primary goal is to ensure maximum benefit to society. We therefore take steps to ensure that licensees achieve this.

7. **Is there a market for this product?**

   Yes – Fish oils and astaxanthin are now more valuable than vegetable oil and currently estimated to be worth over £10 billion/year globally.

8. **Are you going to put the knowledge gained from this trial in the public domain?**

   Yes the results will be published after peer review in the appropriate scientific journal and we will make them accessible on our website.