Pearson BTEC Level 3 Nationals Extended Diploma

7 May 2019 – 21 May 2019

Supervised period: 6 hours	Paper Reference **31629H**

Applied Science

Unit 7: Contemporary Issues in Science

Part A

You do not need any other materials.

Instructions

- **Part A** contains material for the completion of the preparatory work for the set task.
- **Part A** is given to learners during the supervised window before **Part B** is scheduled. Learners are advised to spend no more than 6 hours on **Part A**.
- **Part A** must be given to learners on the specified date so that learners can prepare in the way specified.
- **Part A** is specific to each series and this material must only be issued to learners who have been entered to undertake the task in the relevant series.
- **Part B** materials must be issued to learners on the date specified by Pearson.

Turn over ▶

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Pearson

Instructions to Teachers/Tutors

This paper must be read in conjunction with the unit information in the specification and the BTEC Nationals Instructions for Conducting External Assessments (ICEA) document. See the Pearson website for details.

This set task has a preparatory period. **Part A** sets out how learners should prepare for the completion of the **Part B** task under supervised conditions.

Part A is given to learners during the specified window before **Part B** is scheduled. Learners are advised to spend no more than six hours on **Part A**.

Learners should undertake independent research on the case study given in this **Part A** booklet.

Centres must issue this booklet at the appropriate time and advise learners of the timetabled sessions during which they can prepare. It is expected that scheduled lessons or other timetabled slots will be used for the preparation.

Learners should familiarise themselves with the specific concepts and terminology used in the articles.

Learners may prepare summary notes on the articles. Learners may take up to four sides of A4, which may be handwritten or word processed, into the supervised assessment (**Part B** booklet).

These notes should only include information about scientific terminology, quantities and concepts used in the articles and a summary of the scientific issue discussed. This will enable learners to interpret, analyse and evaluate the articles in **Part B**. Other content is not permitted.

Part B must be completed under supervision in a single 2 hours and 30 minute session timetabled by Pearson. A supervised rest break is permitted.

The supervised assessment should be completed in the **Part B** task and answer booklet.
Teachers/tutors should note that:

- learners should not be given any direct guidance or prepared materials
- learners should not be given any support in writing or editing notes
- all work must be completed independently by the learner
- learner notes will be retained securely by the centre after **Part B** and may be requested by Pearson if there is suspected malpractice.

Refer carefully to the instructions in this taskbook and the BTEC Nationals Instructions for Conducting External Assessments (ICEA) document to ensure that the preparatory period is conducted correctly and that learners have the opportunity to carry out the required activities independently.

Instructions for Learners

Read the set task information carefully.

This is **Part A** of the set task and gives information you need to use to prepare for **Part B** of the set task.

In **Part B** you will be asked to carry out specific activities using the information in this **Part A** booklet and your preparatory notes.

In your preparation for **Part B** using this **Part A** booklet you may prepare short notes to refer to when completing the set task. Your notes may be up to four sides of A4 and may be handwritten or word processed. Your notes should only include information about scientific terminology, quantities and concepts used in the articles and a summary of the scientific issue discussed. This will enable you to interpret, analyse and evaluate the articles in **Part B**. Other content is not permitted.

You will complete **Part B** under supervised conditions.

You must work independently throughout the supervised assessment and must not share your work with other learners.

Your teacher/tutor may give guidance on when you can complete the preparation.

Your teacher/tutor cannot give you feedback during the preparation period.

You must not take your preparatory notes out of the classroom at any time and you must hand them in to your teacher/tutor on completion.

Your notes will be made available to you at the beginning of the supervised assessment.

Set Task Brief

You are provided with the following articles:

Article 1: What Is a Genetically Modified Crop? A European Ruling Sows Confusion
https://www.nytimes.com/2018/07/27/science/gmo-europe-crops.html

Article 2: Golden rice's lack of lustre
http://www.greenpeace.org/seasia/ph/PageFiles/194616/Golden%20rices%20lack%20of%20lustre.pdf

Article 3: An overview of agriculture, nutrition and fortification, supplementation and biofortification: Golden Rice as an example for enhancing micronutrient intake
http://goldenrice.org/PDFs/Dubock%202017%20An%20overview%20of%20agriculture,%20nutrition%20and%20fortification,%20supplementation%20and%20biofortification_%20Golden%20Rice%20as%20an%20example%20for%20enhancing%20micronutrient%20intake.pdf

Your notes should only include information about scientific terminology, quantities and concepts used in the articles and a summary of the scientific issue discussed.

You should spend up to a maximum of six hours to complete your preparatory notes. You may take up to four sides of A4 notes into the supervised assessment.

Part A Set Task Information

Article 1

What Is a Genetically Modified Crop? A European Ruling Sows Confusion

Written by: Carl Zimmer, 27 July, 2018

A version of this article appears in print on July 28, 2018, on Page B5 of the New York Times edition with the headline: What is a Genetically Modified Crop? European Court Ruling Sows Confusion.

In Europe, plants created with gene-editing technologies will be stringently regulated as GMOs. But older crops whose DNA has been altered will be left alone.

A wheat field in Mouchamps, France. There are very few genetically modified crops grown in Europe compared to the United States.

Photograph: Regis Duvignau/Reuters

Mushrooms that don't brown. Wheat that fights off disease. Tomatoes with a longer growing season.

All of these crops are made possible by a gene-editing technology called CRISPR-Cas9. But now its future has been clouded by the European Union's (EU) top court.

This week, the court ruled that gene-edited crops are genetically modified organisms, and therefore must comply with the tough regulations that apply to plants made with genes from other species.

Many scientists responded to the decision with dismay, predicting that countries in the developing world would follow Europe's lead, blocking useful gene-edited crops from reaching farms and marketplaces. The ruling may also curtail exports from the United States, which has taken a more lenient view of gene-edited foods.

"You're not just affecting Europe, you're affecting the world with this decision," said Matthew Willmann, the Director of the Plant Transformation Facility at Cornell University.

But the ruling also raises a more fundamental question: What does it actually mean for a crop to be genetically modified?

In its decision, the European Union court exempted crops produced through older methods of altering DNA, saying they were not genetically modified organisms. That assertion left many scientists scratching their heads.

“I don’t know why they are doing that,” said Jennifer Kuzma, an expert in genetic engineering at North Carolina State University. “I was thinking, ‘Do they have the right science advice?’”

Since the agricultural revolution 10,000 years ago, all crop breeding has come down to altering the genetic composition of plants. For centuries, farmers selected certain plants to breed, or crossed varieties, hoping to pass useful traits to future generations.

In the early 20th century, scientists discovered genes and invented new ways to breed crops. Two lines of corn, for example, could be melded into hybrid plants that were superior to either parent.

By the 1920s, researchers realized that they didn’t have to content themselves with amplifying the genetic variations that already existed in plants. They could create new mutations.

To do so, they fired X-rays at plants or used chemicals that disrupted plant DNA. Mutagenesis, as this method came to be known, introduced random mutations into plants.

Scientists inspected the mutants to find those that were improvements. Thousands of plant breeds in use today, from strawberries to barley, are the product of mutagenesis.

In the 1970s, microbiologists figured out how to insert genes from humans and other species into bacteria. Plant scientists later used recombinant DNA, as the technology came to be known, to develop methods for inserting genes into plants to improve their growth.

Some varieties of corn, for example, received a gene from bacteria that allowed the crops to produce an insect-killing toxin. These came to be known as genetically modified crops, and they sparked a storm of controversy.

Environmental groups such as Greenpeace and Friends of the Earth raised concerns that genetically modified crops posed unpredictable dangers.

The plants might escape farmers’ fields and spread through wild ecosystems, for instance, perhaps hybridizing with wild plants and introducing their genes into new species.

Environmental groups also raised the possibility that genetically modified crops could harm human health. Genetically modified crops not only produce proteins from their own genes, but from the genes of other species, as well.

On opposite sides of the Atlantic, the conflict has played out in very different ways.

In the United States, the National Academy of Sciences has found no evidence to confirm that these crops are any more dangerous than conventionally bred ones.

While the government has put in place a number of regulations governing genetically modified crops, the industry has boomed. Over 185 million acres of these crops were planted in the United States in 2017.

In Europe, by contrast, concerns about genetically modified organisms led the European Union to issue a directive in 2001. From the early stages of research to the marketplace, these products would have to pass a series of tests for environmental risks and human safety.

But the directive made it clear that crops made through older forms of mutagenesis were not genetically modified organisms because they were “conventional” and had “a long safety record.”

The result of the directive has been that Europe grows almost no genetically modified crops. In 2017, only 325,000 acres were planted across the continent.

In the years after the EU's directive came out, science advanced beyond recombinant DNA. Rather than inserting a gene from another species, researchers learned to snip out a piece of a plant's DNA, or even rewrite short stretches of genetic material.

Instead of inserting foreign genes, scientists were able to edit a plant's own DNA in new ways. They could create crops that make more, or fewer, proteins from their own genes, gaining advantageous traits.

When scientists first started experimenting with gene editing on crops, the European Union offered no clear guidance. In 2015, a French agricultural union and allies such as Friends of the Earth went to court to have gene-edited crops labeled as genetically modified organisms – and regulated as such.

And now the court has agreed. In a statement, the court said gene-edited crops were GMOs "within the meaning of the GMO Directive."

Dana Perls, the senior food and agriculture campaigner at Friends of the Earth, praised the court for recognizing gene editing as genetic modification. "We need to call it what it is," she said.

Ms. Perls said that CRISPR and other new methods for tinkering with plant DNA raise concerns about safety, just as recombinant DNA did.

"Gene-editing technologies have unintended consequences," she said.

Ms. Perls pointed to some scientific journal articles that describe how CRISPR and other forms of gene editing can miss their targets, accidentally altering other stretches of DNA in an organism.

But one of the authors of those papers, Jeffrey D. Wolt, a professor of agronomy and toxicology at Iowa State University, was dismayed by the EU court ruling.

"It all boils down to legal interpretations of the directive rather than the weight of the science," he said.

Dr. Wolt said that it's important to distinguish CRISPR research on plants and the use of gene editing to develop new medical treatments.

There are many opportunities in plant experiments to screen out unwanted mutations. As a result, the chances of unexpected mutations in gene-edited plants are falling to low levels.

Dr. Wolt said that there wasn't a strong scientific reason to consider gene-edited plants to be GMOs while exempting crops created in the old way, with X-rays and chemicals producing many random mutations at once. "It's hairsplitting," he said.

The United States is continuing to veer from Europe. In March, the Department of Agriculture (U.S.D.A.) announced that it was not planning to regulate gene-edited crops as it does crops with foreign genes inserted with recombinant DNA.

As a result, CRISPR-edited crops like mushrooms are expected to move quickly into the American marketplace. But these crops may be barred from import into Europe.

Strictly speaking, however, the United States stance also is contradictory. Crops created with recombinant DNA are said to be genetically modified organisms, because genes have been inserted into their DNA.

Yet tinkering with a plant's DNA with CRISPR is apparently not genetic modification, because these crops "are indistinguishable from those developed through traditional breeding methods," according to a U.S.D.A. statement issued in March.

Dr. Wolt said that the only way to escape these contradictions would be for government regulators to stop focusing on mutagenesis, recombinant DNA, CRISPR and other methods for making new crops. “It’s the products we should be concerned with,” he said.

“As soon as we solve this problem favorably or unfavorably for CRISPR, there’s going to be a new technology that comes along and we’re going to have the same problem again.”

Article 2

Golden rice's lack of lustre
Addressing vitamin A deficiency without genetic engineering

Written by: Amy King, Mario Rautner, Glen Tyler, 9 November, 2010

This is an edited version of a publication by Greenpeace International.

Introduction

Vitamin A deficiency (VAD) continues to be one of the most serious health problems in the developing world. The last two decades have seen tremendous improvements in the treatment of VAD, and it has been virtually eliminated among specific sectors of the population in many countries. The number of countries achieving vitamin A supplementation (VAS) targets nearly doubled between 2003 and 2005. These improvements are due to a combination of four strategies, well-tested and proven to be successful: vitamin A supplementation with capsules, the fortification of food with vitamins and minerals, oral supplements or food additives, and dietary diversification.

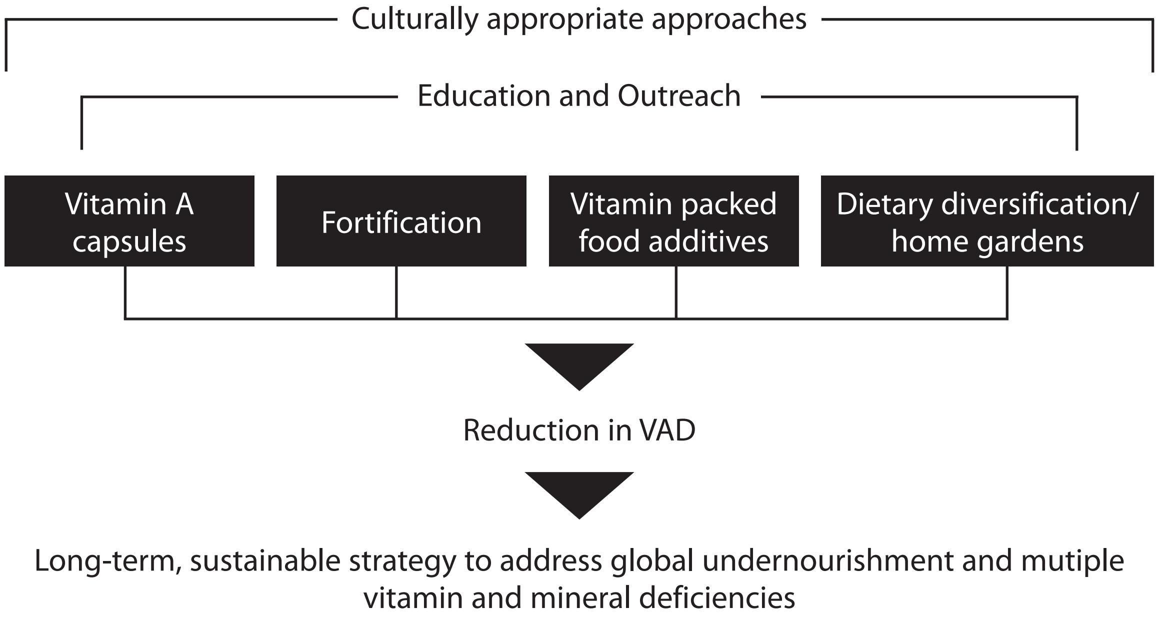


Figure 1. A diverse approach to VAD ensures long-term success.

However, VAD has also been used as a reason to develop so-called 'golden' rice – a variety of rice that has been genetically-engineered (GE) to biosynthesise beta-carotene, a precursor of vitamin A, in the inner edible parts (endosperm) of rice.

Greenpeace considers the term 'golden rice' to be a misnomer – calling this rice 'golden' suggests that it is a panacea or miracle cure, which – after 20 years of development, millions of dollars of funding and significant promotion by a number of organisations – it clearly is not.

The marketing of so-called golden rice is often promoted as a solution to VAD in countries where rice is a staple food. This solution is not only ecologically irresponsible – introducing GE rice on the Asian continent, a centre of origin and diversity for rice, has the potential to contaminate invaluable genetic resources for combating future disease in rice varieties – but it also misses the point: **VAD is routinely associated with other nutritional deficiencies**. Thus, programmes that improve the intake of all necessary vitamins and minerals and promote access to a healthy balanced diet are the only truly sustainable solution to the widespread problem of chronic undernourishment.

Addressing VAD: Success Stories – Asia

While Asian countries have made considerable progress in combating VAD in recent years, South Asia remains the most seriously affected region in the world. Nearly half of all VAD and xerophthalmia (extreme dryness of the eyes) cases occur in south and southeast Asia (UNSCN 2004). Efforts to combat VAD in the region are substantial; in 2008, of children under 5 years old, 70% are receiving full VAS in Asia (UNICEF 2009). Foods fortified with vitamin A are available in Malaysia and the Philippines, with some progress towards fortification in the Democratic People's Republic of Korea, Indonesia, Thailand and Vietnam. South Asia is also working toward fortification of oil-based staples such as ghee (UNICEF 2007a).

Despite the work left to be done, successful models for combating VAD in this region are abundant.

Work done by Helen Keller International (HKI) in Bangladesh over the last four decades provides a particularly impressive model for the eradication of VAD. Rural Bangladesh is one of the most undernourished regions of the world, with 46% of children under five underweight and 36% of mothers chronically energy deficient (HKI/IPHN 2006a). Micronutrient deficiencies affect 50% of children and women of reproductive age (HKI/IPHN 2006a). In the early 1990s, HKI began a home gardening project in rural Bangladesh to address VAD. This has since been expanded to a formal Homestead Food Production (HFP) programme to include animal husbandry and consumption of animal products (HKI/IPHN 2006b) on thousands of rural properties, largely managed by women (HKI 2010). HFP and other food-based strategies have increased food security, reduced micronutrient deficiencies and empowered women in Bangladesh (Bushamuka et al. 2005). The wide-ranging benefits of these programmes have included a lowered risk of night blindness in children living in homes with a homestead garden (Talukder et al. 2000) and increases in pro-vitamin A carotenoid intake (de Pee et al. 2007). Following implementation of the HFP programme, Bangladeshi mothers' daily consumption of pro-vitamin A carotenoid from vegetables and fruits increased eightfold, and their children's (aged under 5 years) consumption increased fourfold (Taher et al. 2004). Combined with the availability of vitamin A-fortified wheat flour, VAD and night blindness are no longer at a level to be considered a public health problem in children under 5 in Bangladesh (UNICEF 2007b).

Country	**Bangladesh**	**Philippines**	**Pakistan**
VAD reduction strategy	• Vitamin A capsules • Fortifications • Dietary diversification/home gardens	• Vitamin A capsules • Fortifications • Vitamin packets/food additives • Dietary diversification/ home gardens	• Vitamin A capsules • Dietary diversification/home gardens
Success stories	HFP programme shown to reduce night-blindness, dramatically increase pro-vitamin A uptake in mothers and children.	86% of children receive 2 annual VAS doses; holistic approach includes home, school and community food production, micronutrient supplementation, food fortification, food assistance and nutrition education.	Since 2003, incidence of VAD has dropped from between 35% and 48% of children to less than 5%; government programmes are promoting the intake of green vegetables, yogurt and mangos to address multiple micronutrients.
Status	VAD below 5%	VAD below 5%	VAD below 5%
Source(s)	See above paragraph	Barba and Feliciano 2002; UNSCN 2006a	Sher 2003; WHO database 2010; UNICEF 2009; Khan et al. 2006; Panhwar 2005

So-called 'golden' rice: a distraction

So-called 'golden' rice has been under development since 1990 (Potrykus, 2000). However, the first prototype was unveiled only in 2000 (Ye et al. 2000). Once the intention to commercialise the rice was announced, it was accompanied by a strident media campaign asserting that it could save millions of lives: the headline "This rice could save a million kids a year" appeared on the front page of Time magazine (2000). The developers also placed moral pressure on organisations or institutions opposed to the cultivation of GE crops: "The consequences will be millions of unnecessary blind children and Vitamin A deficiency related deaths." (Potrykus, 2001).

In 2004, Syngenta claimed that it had harvested the first field trial of golden rice in the US, in collaboration with Louisiana State University. It is ironic that the reason for this was that "the USA is one of the few countries in the world where field trials with transgenic (GE) plants can be carried out after complying with an acceptable, well-defined set of regulatory requirements" (Golden Rice Project 2008c). In 2006, an experimental rice variety LL601 was found to have contaminated the US rice supply chain (USDA 2006). As the US Department of Agriculture's Animal and Plant Health Inspection Service has reported, the LL601 contamination originated from Louisiana State University, the same University responsible for the first field trials of golden rice (USDA APHIS 2007). Thus, the possibility of contamination with this experimental GE rice is very real.

Funding 'golden' rice

Over the last 15 years many organisations have been involved in the funding and development of golden rice. The initial stage of the development was financed by ETH Zurich, the Rockefeller Foundation, the Biotech-Programme of the European Union (as part of the Carotene Plus project) and by the Swiss National Science Foundation to a total of $2.6 million US dollars (ETH 2004).

Currently, the funding of the so-called 'golden' rice is often channelled through the International Page Rice Research Institute (IRRI), which has been critical in the development of the rice. The idea to develop 'golden' rice came from a discussion at IRRI in 1984 and to this day IRRI is also the base of the Golden Rice Network (IRRI 2009c).

Beyond 'golden' rice, IRRI is researching the development of a number of other GE rice varieties. Most of the funds for these projects are provided by the Bill & Melinda Gates Foundation. In fact in total the Foundation has provided at least 71% of the funds available to current GE projects at IRRI (Table 3). These GE rice projects include traits for:

- drought, heat, and salinity tolerance;
- increased photosynthetic capacity to improve yield and enable more efficient water and nitrogen fertiliser use (C_4 rice); and
- increased nutritional value of the grain, including improved protein quality, and higher iron content (IRRI 2010b).

Table 3. Major IRRI grants received related to projects that include research on GE plants since 2008 (IRRI 2009, 2010c). All values in $1,000 US dollars. Grants likely related to golden rice are highlighted in grey.

Donor	Grant period	Total grant	2018 expenditure	Previous years expenditure	Project
Gates Foundation	15/10/08 – 31/10/11	11,017	11,017	–	Creating the Second Green Revolution by Supercharging Photosynthesis: C_4-rice
Gates Foundation	01/12/08 – 31/11/11	19,954	19,954	–	The Cereal Systems Initiative for South Asia (CSISA)
China	11/01/08 – 31/10/11	4,633	4,633	–	"Green Super Rice" for the Resource-Poor of Africa and Asia
Albert-Ludwig's University of Freiburg	28/09/05 – 27/09/10	1,213	1,213	306	Engineering Rice for High Beta-Carotene, Vitamin E and Enhanced Iron and Zinc Bioavailability
HarvestPlus	01/01/03 – 31/12/08	2,203	2,203	1,664	Biofortified Crops for Improved Human Nutrition
HarvestPlus	2010 – ?	n/a	n/a	n/a	Equipment support to the Workplan "Development of Golden Rice for Philippines, Bangladesh, and Eastern India"
USA (USAID)	01/01/05 – 31/12/09	385	385	59	The Development of Adapted Germplasm for India with High Levels of Pro Vitamin-A Carotenoids
Rockefeller Foundation	1/1/2009 – 31/12/2012	4,000	4,000	n/a	Golden Rice Product Development and Deployment

Conclusions

There is ample evidence that the so-called 'golden' rice is a misguided answer to vitamin A deficiency and malnutrition that will have minimal impact while costing millions of dollars. Instead, those funds would be more wisely invested in successful VAD treatment programmes, already tried and tested in many countries. By looking at the root causes of vitamin A deficiency, projects such as Homestead Food Production have tackled not only VAD, but also other vitamin and mineral deficiencies in the process. Those genuinely concerned with the eradication of VAD face a choice; devote additional resources to untested, costly experiments which stand to endanger the diversity of rice genetic resources, or scale up existing and proven solutions, without any risk of genetic contamination.

Greenpeace promotes ecological farming that ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity, and does not contaminate the environment with chemical inputs or genetic engineering.

Source: Greenpeace (http://www.greenpeace.org)

Article 3

An overview of agriculture, nutrition and fortification, supplementation and biofortification: Golden Rice as an example for enhancing micronutrient intake

Written by: Adrian Dubock, 6 October, 2017

This is an edited version of a review paper published in the Agriculture & Food Security open access journal.

Abstract

The world's growing population and limited land resources require high intensity of food production. Human nutrition needs both macronutrients and micronutrients. One way of providing micronutrients in staple crops of the poor is biofortification, through plant breeding. All methods of plant breeding are acceptable and safe, and some methods can deliver micronutrients not achievable by other methods. Vitamin A deficiency is responsible for around 4500 preventable child deaths daily, and Golden Rice, biofortified with provitamin A, has proven potential as a costless intervention where rice is the staple crop. Attitudes to GMO crops, after two decades, appear to be changing, which is expected to benefit humankind and the environment.

Keywords: Food security, Biofortification, Vitamin A deficiency, GMO crops, Golden Rice, Greenpeace

Human population, agriculture and food production

Around 71% of the world's surface is covered by water, which contributes only 1% of human food. Less than 20% of the land area is suitable for agriculture. So less than 6% of the world's surface must produce the food humans need [1]. The human population has more than doubled in the last 50 years from 3.5 billion to 7.5 billion today and will reach almost 10 billion people in the next 50 years [2].

For 12,000 years, humans have been continuously breeding crops for increased yield: mostly carbohydrates, an excellent human energy source. The trend to more intensive production by fewer people has accelerated over the past 150 years with science and innovation driving the change: synthetic fertilisers, herbicides, fungicides and insecticides, plant breeding techniques, mechanisation and irrigation, as well as since the late 1990s the incorporation, through transgenesis – resulting in "GMO crops" – of genetic traits. Agriculture has the biggest negative impact on biodiversity of cultivated land. And yet intensive agriculture is the kindest for maintenance of global biodiversity by protection of wild lands from food production. In the industrialised countries, for most of the time following WWII, there has been an increasing ubiquity, often imported, of plentiful and nutritious food at low prices, around 10% of family income. Larger farm units lead to economies of scale in production. Only around 2% of the population are farmers and produce the food for all. Ninety-eight percent of the population have little understanding of agriculture or the technology involved, and as food is an emotional subject, it is easy to stimulate fear of food production systems. In the non-industrialised countries, in contrast, food production is often under-resourced, requiring in some countries 60–70% of the population to be farmers. Very small farms are the norm. Land tenure and market access are two of many issues which exacerbate the difficulties in food production. Farming is not a high-status occupation, and there is a continuing migration of labour from the land in the expectation of a better life in cities. For those left behind, often the old, the work becomes ever more demanding, and less productive, with a tendency to increasing poverty. With inefficient production and poverty, food takes up a huge proportion (perhaps 50%) of available family income in these countries.

Following World War II in many countries, there were food shortages. Food rationing in the UK only ceased in July 1954. From the 1940s, the international nutritional focus was on macronutrient sufficiency. Human population was starting to increase rapidly. Nevertheless, in all regions of the world except Africa, per-capita food production increased for the four decades following the 1960s Green Revolution [3].

Per-capita food production, 1961 and various years

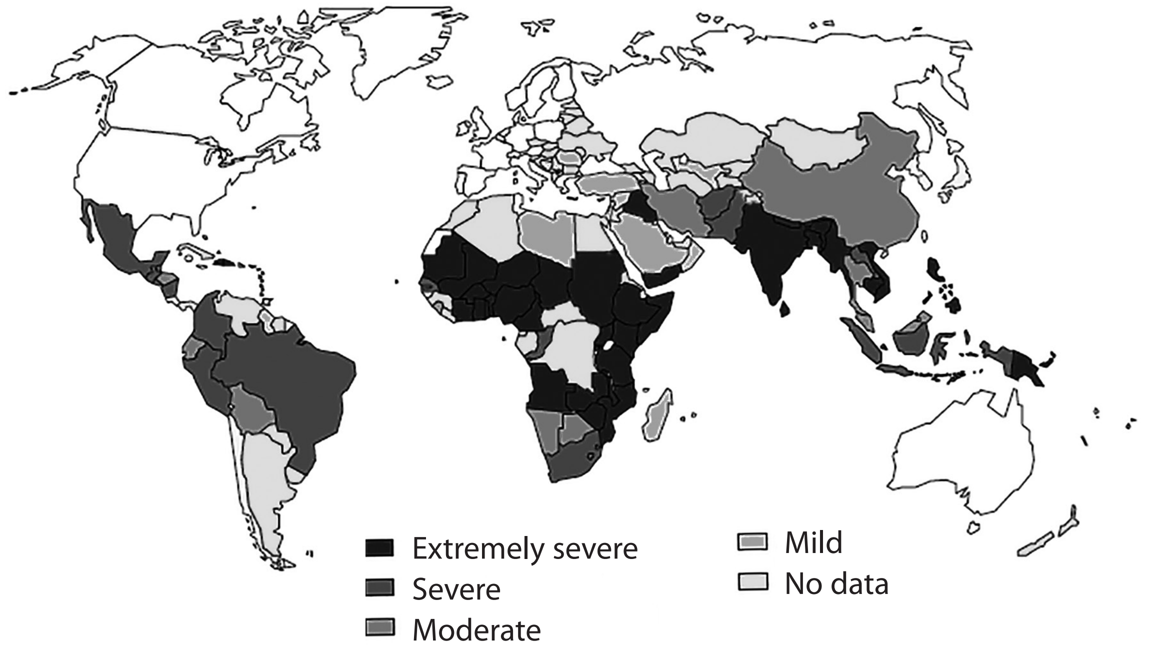
Continent	1961	1971	1981	1991	2001
Africa	100	103	94	90	90
Asia	100	104	114	134	173
South America	100	100	115	118	144
World	100	107	112	115	126

"According to the Food Security Index 2016, developed western countries hold the highest levels of food security while sub-Saharan African countries are at the bottom of the rankings. Germany and France, which have opted out of cultivating GMO crops – both ranked 6/113; in contrast, Kenya ranked 83 and Mozambique 108". "…why should Africa be prohibited from growing the most technologically advanced and sustainable crops?" "[African] Farmers need and want choices, not European-imposed restrictions" [8]. Especially as Africa's population is forecast to experience by far the largest percentage change (>100%) of all global regions between 2015 and 2050 [9]. Poverty is often associated with very limited dietary diversity. Carbohydrate-rich grains are an important energy source. The other macronutrients, fats and proteins, are important too. However, humans also need micronutrients – minerals such as iodine, iron and zinc and vitamins such as vitamins A, C, D, B_1 and B_3 for healthy development and life. Micronutrients exist as either minerals, taken up from the soil and accumulated by plants, or vitamins that are synthesised either by plants or by animals. Energy-rich grains are extremely important, but without dietary diversity are not sufficient for a healthy life [5]. In industrialised countries, dietary diversity includes not only plant products, but also animal products, and populations with such a varied diet generally benefit from sufficiency of both macronutrients and micronutrients. Often poor people in developing countries have very limited access to animal products, for economic or other reasons.

Vitamin A deficiency

Human populations deficient in the minerals such as iron and zinc, and in vitamin A, suffer from a variety of serious developmental and public health issues, and these deficiencies are more widespread globally than other important micronutrient deficiencies [5]. Vitamin A deficiency, VAD, which mostly affects children less than 5 years old, and to a lesser extent their mothers, is widespread and well documented by the World Health Organisation [18].

Public health importance of vitamin A deficiency, by country



Source: WHO data. Redrawn by and produced courtesy Banson

By the 1990s, VAD was known as the major cause of childhood blindness globally, with about 500,000 cases annually, of which about two-thirds die if not treated [19]. As a result, for more than a quarter of a century, vitamin A deficiency (VAD) has been recognised by the United Nations as a significant public health problem.

What was not known clearly in the 1990s was that VAD also suppresses the human immune system: VAD is "a nutritionally acquired immune deficiency syndrome" [12]. Eyesight problems and immune deficiency-related deaths are two different morbidities of vitamin A deficiency. Most who die as a result of VAD do not become blind first. Increased susceptibility to disease as a result of VAD results in the majority of the millions of preventable < 5-year-old child deaths, mainly among children, annually [23, 24].

A universally available source of vitamin A could save 23–34% of all deaths of children under 5 years old globally and reduce measles mortality by up to 50% [23, 26]. As the UN regularly measures and publishes global all-cause child mortality [27, 28], the importance of VAD mortality can be stated compared with other public health mortality causes especially important in the countries where poverty is widespread:

Global mortality from important public health diseases

Global mortality (millions)	**2010**	**2014**
Vitamin A deficiency	1.9–2.8	1.4–2.1
HIV / AIDS	1.8	1.2
Tuberculosis	1.4	1.1
Malaria	0.7	0.6

Data sources: For 2010 data [24]; for 2014 data [23, 29–32]

Why is combatting VAD such a challenge? Only animals, including human beings, synthesise vitamin A. No plants contain vitamin A. The only direct sources of vitamin A itself are animal products: liver, butter, milk and eggs are excellent sources. Animals and humans synthesise vitamin A from carotenoid chemicals naturally occurring in coloured fruits, vegetables and leaves. Beta carotene (β-carotene) is a particularly important provitamin A carotenoid found in all coloured plant foods. In industrialised countries, VAD is not a significant problem because a varied diet includes animal products and various sources of provitamin A carotenoids, and also there is widespread fortification of food products together with the use of vitamin supplements by newborns and pregnant and lactating women. In the poorer sections of developing countries, food sources that are most valuable in terms of micronutrients – animal products including milk, eggs, butter, liver and fish – are usually more expensive and "beyond the reach of poor families" [12].

Biofortification and Golden Rice

There are several strategies for addressing micronutrient deficiencies caused by insufficient dietary diversity. Industrial fortification (e.g. adding iodine to salt, vitamins A and D to margarine, fluoride to toothpaste, folic acid to flour) has been used successfully to ensure sufficiency of micronutrients to populations. Supplementation involves provision and consumption of tablets, syrup or capsules containing micronutrients and has also been employed in both industrialised and developing countries. Both fortification and supplementation, however, require some level of manufacturing and/or distribution infrastructure, and the micronutrients need to be paid for, even if they are free to the consumer. As a result, the most marginalised, and the neediest may not benefit.

In 2000, two German professors, Ingo Potrykus and Peter Beyer, proved that they could modify the genome of white rice to produce beta-carotene, the precursor which the human body uses as a source to make vitamin A [42, 43]. They then donated the technology involved in the creation of Golden Rice to benefit the disadvantaged in the developing world, mindful particularly of the intractable vitamin A deficiency problems in India and other countries of Asia. Their interest in the humanitarian use of their technology was not inconsistent with commercial interest (from 2000 to 2004) for industrialised countries for the same technology by the company Syngenta. The first licensee of the Golden Rice inventors, in 2001, was the International Rice Research Institute (IRRI) a not-for-profit institute established in the Philippines. All the other 15 Golden Rice licensees are rice laboratories of national governments. "Golden Rice" is the first purposefully created biofortified food. It is a rice that synthesises and accumulates β-carotene during seed maturation [42]. Following normal harvesting, grain polishing, storage, cooking and consumption, the human body efficiently converts the β-carotene in Golden Rice to vitamin A [44]: "In summary, the high bioconversion efficiency of Golden Rice beta-carotene to vitamin A shows that this rice can be used as a source of vitamin A. Golden Rice may be as useful as a source of preformed vitamin A from vitamin A capsules, eggs or milk to overcome VAD in rice-consuming populations" [24]. Calculations suggest that 40 g of dry Golden Rice, after normal harvest, polishing, storage and cooking, when consumed daily, will save the life and sight of people who would otherwise be vitamin A deficient [24].

Plant breeding and safety

Traditionally improvements to plants have been achieved by crossing plants of the same species, observing the plants which arise from the random mixing of genes which occurs in the reproductive process, and selecting the individual plants with the most useful characteristics for the next round of cross-breeding. Over 12,000 years, the approach has gradually improved domesticated plants. Initially, it was carried out by the early farmers, and since the latter part of the 1800s by more specialised plant breeders, who increasingly combine careful observation and record keeping with biological understanding. Contrary to other claims to the accolade, it is probably plant breeding which is "the oldest profession". When the inventors of Golden Rice started out, they considered four different scientific approaches [33]. Because there was no rice variety which exhibited yellow grains, there was no variability to exploit through the conventional plant crossing route, and it was unlikely to be effective to mutagenise rice seeds or plants. But they knew that genes inducing a yellow colour were present in some easily obtainable plant tissues. By selecting the genes giving the yellow colour to daffodil (narcissi) flowers, and introducing them to the rice genome in a way which allowed gene (and therefore colour) expression in rice seed, they were able to create the prototype Golden Rice [42, 43]. Subsequently, the Syngenta scientists took other genes known to be associated with beta-carotene synthesis in seeds, those from maize, and were able to induce synthesis of higher levels of beta-carotene, both in micrograms and in percentage of total carotenoids [49]. It is this latter approach which is the basis of Golden Rice today. From either the daffodil or maize, the genes were combined with the rice genome using the genetic modification technique "transgenesis": so Golden Rice is a "GMO" (genetically modified organism). But only once, in about 2004 for today's Golden Rice: since 2004, for the past 13 years, all subsequent development of Golden Rice has been through "conventional" cross-breeding. Much has been made of the potential differences for safety to man, animals or the environment between conventionally bred crops and GMO crops. These concerns are often conflated and inflated by association with dislike of the commercial behaviour of companies which have been most associated with the introduction of GMO crops. This is unfortunate because the effect is to reduce the ability of non-commercial entities to utilise the power of genetics, so beneficially harnessed in medicine and food processing [33, 60], to benefit food production. Conversely, all independent science-based institutions globally [50–54] have found crops produced by transgenesis to be of no more concern than crops produced by any other method. There are many references, but a particularly clear one comes from the heart of the geography politically most opposed to GMO-technology, the European Commission: "The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than, for example, conventional plant breeding technologies" [51].

Economics

It has been calculated that conservative adoption of Golden Rice in Asian countries would add ~US$6.4 billion to those countries GDP through increased productivity enabled by reduced vitamin A deficiency-induced sickness, and improved eyesight, and ~US$17.4 billion if Golden Rice adoption encouraged adoption of other nutritional traits to rice, through increased productivity [55]. Compared with the cost of other VAD interventions, Golden Rice, fully costed with all development costs, has been calculated to be at a minimum six times cheaper per "disability adjusted life year" saved [33]. This is because all the costs are "up front". The nutritional technology is in the seed, and once adoption by an area's population is assured, very little cost will be involved in project maintenance or refreshment. The seed reproduces itself, and can be replanted, mostly in the localities where it will be consumed to deliver its nutritional benefits – energy and a source of vitamin A. Undue delay in India to making Golden Rice available has cost the Indian economy US$199 m per year for a decade [56]. Combatting micronutrient deficiencies has been judged at all three separate meetings by different panels of Nobel Laureate Economists as part of the Copenhagen Consensus process, as "the best bang for a buck", that is, the most cost-effective way to solve 30 major problems faced by the world [33]. With the donation terms of the Golden Rice inventors making Golden Rice cost no more than white rice to aid agencies, or governments or consumers, the cost-benefit of Golden Rice where rice is the staple and VAD endemic is expected to be magnificent with no need to change any cultural practices, except the adoption of Golden Rice instead of white rice by growers and consumers. Vitamin A capsules, currently costing about US$1.00 billion per year [24], are only recommended for children of 6 months and older [38], as very young children do not consume solid food. The capsules are not recommended for children younger than 6 months due to toxicity concerns from the vitamin A [39], yet these very young children are the most vulnerable to vitamin A deficiency: neonate deaths in 2011 accounted for 43% (increased from 36% in 1990) of all deaths among under 5 year olds [27]. It is anticipated, but so far unproven, that a good source of vitamin A, such as Golden Rice, when part of the staple diet, can improve the mother's vitamin A status, benefiting her health, and simultaneously via the placenta and breast milk increase her baby's resistance to disease.

Anti-GMO-crop political activism

The seminal Ye et al. paper [42], published on 14 January 2000, announced that the teams of Potrykus and Beyer had succeeded in their "proof of concept" research, demonstrating that the genome of white rice could be changed so that it synthesised and accumulated beta-carotene in the endosperm. It was published in the high-impact journal "Science", published in the USA, after the UK published journal "Nature" had rejected it. This was a gentle portend of political opposition to Golden Rice to come: Europe had been vociferously opposing all GMO crops for the previous 3 years. From this beginning, for the last 16 years, there has been an ongoing low level but impactful publicity insurgency against the Golden Rice humanitarian project by anti-GMO activists, punctuated by a few large battles. Many anti-GMO activist organisations have been involved. The most strident and constant has been Greenpeace.

Greenpeace Press Release, 2012. On 8 August 2012, Tang et al. published online the results of research initially planned in 2003 and completed in June 2008. The authors found: "*In summary, the high bioconversion efficiency of Golden Rice b-carotene to vitamin A shows that this rice can be used as a source of vitamin A. Golden Rice may be as useful as a source of preformed vitamin A from vitamin A capsules, eggs or milk to overcome VAD in rice-consuming populations*".

Greenpeace commented 3 weeks later, on 29 August 2012: "*Greenpeace alarmed at US-backed GE food trial on Chinese children" "It is incredibly disturbing to think that an American research body used Chinese children as guinea pigs for genetically engineered food,…………. The relevance of this study is questionable … Nor does high conversion rate solve all the technical, environmental and ethical issues around Golden Rice*" [60].

Following this Greenpeace Press release, and despite Tufts University finding "*no concerns related to the integrity of the study data, the accuracy of the research results or the safety of the research subjects*" [45], Tang et al. 2012 was retracted by the American Society of Clinical Nutrition in 2015 [62].

Science Editorial commenting on Golden Rice Field Trial destruction, Philippines, 8 August 2013: "*The global scientific community has condemned the wanton destruction of these field trials, gathering thousands of supporting signatures in a matter of days. If ever there was a clear-cut cause for outrage, it is the concerted campaign by Greenpeace and other non-governmental organizations, as well as by individuals, against Golden Rice……………. We, and the thousands of other scientists who have signed the statement of protest, stand together in staunch opposition to the violent destruction of required tests on valuable advances such as Golden Rice that have the potential to save millions of impoverished fellow humans from needless suffering and death*." [65]

Many activists' initial objections to GMO crops are that they were only for industrialised farmers, in industrialised countries, for multinational profit and with no consumer benefit; that they were dangerous for environmental and human health, and their exploitation involved intellectual property rights which would eventually lead to commercial domination of food production. When it was demonstrated that Golden Rice, a GMO crop, did not conform with this stereotype, first of all the activists tried to prove it could not be effective and then tried to vilify or destroy the research which demonstrated its potential. Finally, after demolition of all their arguments, they claimed that Golden Rice was a "Trojan Horse" being manipulated by its proponents merely as a device to create more valuable commercial opportunities for multinational companies to exploit GMO crops, create new farmer dependencies and remove farmer choice.

Conclusion

The public sector holds the responsibility for public health delivery through biofortification of food security crops. For micronutrient biofortification especially, plant breeders need rapidly to catch up with the 12,000-year head-start of seed breeding for yield. Precision agriculture – including GMO crops – now provides the tools to assist: for macronutrients yield, to adapt yields to climate change and other difficult growing conditions, as well as micronutrients. Most farmers using GMO crops in 2014 – clearly of their free will – did so on small farms in developing countries.

Following submission of regulatory data packages to national authorities, it can be anticipated that Golden Rice will be cleared as safe to humans, animals and the environment and made available to countries and populations which want to incorporate it into their culture of rice cultivation and consumption.

Over time, independent research will be undertaken to measure the effect of Golden Rice's regular consumption on vitamin A status of individuals and populations. And in the longer term, on the effect of Golden Rice's regular consumption on the morbidity and mortality of populations which adopt it as a routine part of the staple diet.

Subsequently, if donors are not too fatigued to pay for the development, other micronutrient traits will be combined with the provitamin A beta-carotene in multi-vitamin and multi-mineral rice. Proof of concept has already been achieved for some, a long time ago for folate, and more recently for iron and zinc.

Individuals in developing countries, following registration of Golden Rice, can manage its adoption as a routine part of agriculture and consumption, themselves, without western philanthropic or aid or non-governmental organisation assistance. The result will be truly dignified and sustainable. And a major contribution to alleviation of the effects of poverty, while other methods continue to be targeted at poverty alleviation itself.

The delay to Golden Rice's development has been principally due to suspicion and political interference continuously experienced since first strongly expressed in 2000. The project should have been where it is today, with the major part of a regulatory package finished, in around 2006, 11 years ago.

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson BTEC Level 3 Nationals Extended Diploma

Centre Number

Learner Registration Number

Tuesday 21 May 2019

Morning (Time: 2 hours 30 minutes) | Paper Reference **31629H**

Applied Science

Unit 7: Contemporary Issues in Science

Part B

You will need:
Up to four sides of A4 notes from Part A

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and learner registration number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Part A** will need to have been used in preparation for completion of **Part B**.
- **Part B** must be undertaken in a single session of 2 hours and 30 minutes in the assessment session timetabled by Pearson.
- **Part B** materials must be issued to learners for the specified session.
- **Part B** is specific to each series and this material must only be issued to learners who have been entered to undertake the task in the relevant series.
- **Part B** should be kept securely until the start of the 2 hour and 30 minute supervised assessment.

Information

- The total mark for this paper is 50.
- The marks for each question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- The three articles are at the back of **Part B**.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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P 6 0 4 2 5 A 0 1 3 6

Pearson

Instructions to Teachers/Tutors

This paper must be read in conjunction with the unit information in the specification and the BTEC Nationals Instructions for Conducting External Assessments (ICEA) document. See the Pearson website for details.

Part B set task is undertaken under supervision in a single session of 2 hours and 30 minutes in the timetabled session. Centres may schedule a supervised rest break during the session.

Part B set task requires learners to apply understanding gained through familiarisation with the articles. Learners should bring in notes as defined in **Part A**.

Learners must complete the set task using this task and answer booklet.

Maintaining security

- Only permitted materials for the set task can be brought into the supervised environment.
- During any permitted break and at the end of the session materials must be kept securely and no items removed from the supervised environment.
- Learner notes related to **Part A** must be checked to ensure length and contents meet limitations.
- Learner notes from **Part A** will be retained securely by the centre after **Part B** and may be requested by Pearson if there is suspected malpractice.

After the session the teacher/tutor and/or invigilator will confirm that all learner work was completed independently as part of the authentication submitted to Pearson.

Outcomes for submission

This task and answer booklet should be submitted to Pearson.

Instructions for Learners

Read the set task information carefully.

Complete all your work in this taskbook in the spaces provided**.**

This session is of 2 hours 30 minutes (during the day). Your teacher/invigilator will tell you if there is a supervised break. Plan your time carefully.

You have prepared for the set task given in this **Part B** booklet. Use your notes prepared during **Part A** if relevant. Attempt all the questions in **Part B**.

Your notes must be your own work and will be retained by your centre until results are issued.

You will complete this set task under supervision and your work will be kept securely during any breaks taken.

You must work independently throughout the supervised assessment period and should not share your work with other learners.

Outcomes for submission

You will need to submit the following document on completion of the supervised assessment period:

- a completed **Part B** taskbook.

Set Task

Answer ALL questions in the spaces provided.

1 Discuss the implications of the scientific issue identified in the articles.

(12)

P 6 0 4 2 5 A 0 5 3 6

(Total for Question 1 = 12 marks)

2 Identify the different organisations/individuals mentioned in the articles and suggest how they may have an influence on the scientific issue.

(6)

(Total for Question 2 = 6 marks)

3 Discuss whether Article 3 has made valid judgements.

In your answer you should consider:

- how the article has interpreted and analysed the scientific information to support the conclusions/judgements being made
- the validity and reliability of data
- references to other sources of information.

(12)

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(Total for Question 3 = 12 marks)

4 Suggest potential areas for further development and/or research of the scientific issue from the three articles.

(5)

(Total for Question 4 = 5 marks)

5 You are a junior researcher working for the European Commission for Health and Food Safety.

The European Commission decides whether genetically modified crops can be used.

Many people have concerns about the use of genetically modified crops.

Your task is to write a report about the benefits and concerns of using genetically modified crops.

Your report will be sent to the European Commission, a group of professionals. The professionals are not all scientists.

Use information from the three articles to write your report.

When writing your report, you should consider:

- who is likely to read the report
- what you would like the reader to learn from the report.

(15)

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(Total for Question 5 = 15 marks)

TOTAL FOR PAPER = 50 MARKS

Set Task Information

Article 1

What Is a Genetically Modified Crop? A European Ruling Sows Confusion

Written by: Carl Zimmer, 27 July, 2018

A version of this article appears in print on July 28, 2018, on Page B5 of the New York Times edition with the headline: What is a Genetically Modified Crop? European Court Ruling Sows Confusion.

In Europe, plants created with gene-editing technologies will be stringently regulated as GMOs. But older crops whose DNA has been altered will be left alone.

A wheat field in Mouchamps, France. There are very few genetically modified crops grown in Europe compared to the United States.

Photograph: Regis Duvignau/Reuters

Mushrooms that don't brown. Wheat that fights off disease. Tomatoes with a longer growing season.

All of these crops are made possible by a gene-editing technology called CRISPR-Cas9. But now its future has been clouded by the European Union's (EU) top court.

This week, the court ruled that gene-edited crops are genetically modified organisms, and therefore must comply with the tough regulations that apply to plants made with genes from other species.

Many scientists responded to the decision with dismay, predicting that countries in the developing world would follow Europe's lead, blocking useful gene-edited crops from reaching farms and marketplaces. The ruling may also curtail exports from the United States, which has taken a more lenient view of gene-edited foods.

"You're not just affecting Europe, you're affecting the world with this decision," said Matthew Willmann, the Director of the Plant Transformation Facility at Cornell University.

But the ruling also raises a more fundamental question: What does it actually mean for a crop to be genetically modified?

In its decision, the European Union court exempted crops produced through older methods of altering DNA, saying they were not genetically modified organisms. That assertion left many scientists scratching their heads.

"I don't know why they are doing that," said Jennifer Kuzma, an expert in genetic engineering at North Carolina State University. "I was thinking, 'Do they have the right science advice?'"

Since the agricultural revolution 10,000 years ago, all crop breeding has come down to altering the genetic composition of plants. For centuries, farmers selected certain plants to breed, or crossed varieties, hoping to pass useful traits to future generations.

In the early 20th century, scientists discovered genes and invented new ways to breed crops. Two lines of corn, for example, could be melded into hybrid plants that were superior to either parent.

By the 1920s, researchers realized that they didn't have to content themselves with amplifying the genetic variations that already existed in plants. They could create new mutations.

To do so, they fired X-rays at plants or used chemicals that disrupted plant DNA. Mutagenesis, as this method came to be known, introduced random mutations into plants.

Scientists inspected the mutants to find those that were improvements. Thousands of plant breeds in use today, from strawberries to barley, are the product of mutagenesis.

In the 1970s, microbiologists figured out how to insert genes from humans and other species into bacteria. Plant scientists later used recombinant DNA, as the technology came to be known, to develop methods for inserting genes into plants to improve their growth.

Some varieties of corn, for example, received a gene from bacteria that allowed the crops to produce an insect-killing toxin. These came to be known as genetically modified crops, and they sparked a storm of controversy.

Environmental groups such as Greenpeace and Friends of the Earth raised concerns that genetically modified crops posed unpredictable dangers.

The plants might escape farmers' fields and spread through wild ecosystems, for instance, perhaps hybridizing with wild plants and introducing their genes into new species.

Environmental groups also raised the possibility that genetically modified crops could harm human health. Genetically modified crops not only produce proteins from their own genes, but from the genes of other species, as well.

On opposite sides of the Atlantic, the conflict has played out in very different ways.

In the United States, the National Academy of Sciences has found no evidence to confirm that these crops are any more dangerous than conventionally bred ones.

While the government has put in place a number of regulations governing genetically modified crops, the industry has boomed. Over 185 million acres of these crops were planted in the United States in 2017.

In Europe, by contrast, concerns about genetically modified organisms led the European Union to issue a directive in 2001. From the early stages of research to the marketplace, these products would have to pass a series of tests for environmental risks and human safety.

But the directive made it clear that crops made through older forms of mutagenesis were not genetically modified organisms because they were "conventional" and had "a long safety record."

The result of the directive has been that Europe grows almost no genetically modified crops. In 2017, only 325,000 acres were planted across the continent.

In the years after the EU's directive came out, science advanced beyond recombinant DNA. Rather than inserting a gene from another species, researchers learned to snip out a piece of a plant's DNA, or even rewrite short stretches of genetic material.

Instead of inserting foreign genes, scientists were able to edit a plant's own DNA in new ways. They could create crops that make more, or fewer, proteins from their own genes, gaining advantageous traits.

When scientists first started experimenting with gene editing on crops, the European Union offered no clear guidance. In 2015, a French agricultural union and allies such as Friends of the Earth went to court to have gene-edited crops labeled as genetically modified organisms – and regulated as such.

And now the court has agreed. In a statement, the court said gene-edited crops were GMOs "within the meaning of the GMO Directive."

Dana Perls, the senior food and agriculture campaigner at Friends of the Earth, praised the court for recognizing gene editing as genetic modification. "We need to call it what it is," she said.

Ms. Perls said that CRISPR and other new methods for tinkering with plant DNA raise concerns about safety, just as recombinant DNA did.

"Gene-editing technologies have unintended consequences," she said.

Ms. Perls pointed to some scientific journal articles that describe how CRISPR and other forms of gene editing can miss their targets, accidentally altering other stretches of DNA in an organism.

But one of the authors of those papers, Jeffrey D. Wolt, a professor of agronomy and toxicology at Iowa State University, was dismayed by the EU court ruling.

"It all boils down to legal interpretations of the directive rather than the weight of the science," he said.

Dr. Wolt said that it's important to distinguish CRISPR research on plants and the use of gene editing to develop new medical treatments.

There are many opportunities in plant experiments to screen out unwanted mutations. As a result, the chances of unexpected mutations in gene-edited plants are falling to low levels.

Dr. Wolt said that there wasn't a strong scientific reason to consider gene-edited plants to be GMOs while exempting crops created in the old way, with X-rays and chemicals producing many random mutations at once. "It's hairsplitting," he said.

The United States is continuing to veer from Europe. In March, the Department of Agriculture (U.S.D.A.) announced that it was not planning to regulate gene-edited crops as it does crops with foreign genes inserted with recombinant DNA.

As a result, CRISPR-edited crops like mushrooms are expected to move quickly into the American marketplace. But these crops may be barred from import into Europe.

Strictly speaking, however, the United States stance also is contradictory. Crops created with recombinant DNA are said to be genetically modified organisms, because genes have been inserted into their DNA.

Yet tinkering with a plant's DNA with CRISPR is apparently not genetic modification, because these crops "are indistinguishable from those developed through traditional breeding methods," according to a U.S.D.A. statement issued in March.

Dr. Wolt said that the only way to escape these contradictions would be for government regulators to stop focusing on mutagenesis, recombinant DNA, CRISPR and other methods for making new crops. "It's the products we should be concerned with," he said.

"As soon as we solve this problem favorably or unfavorably for CRISPR, there's going to be a new technology that comes along and we're going to have the same problem again."

Article 2

Golden rice's lack of lustre
Addressing vitamin A deficiency without genetic engineering

Written by: Amy King, Mario Rautner, Glen Tyler, 9 November, 2010

This is an edited version of a publication by Greenpeace International.

Introduction

Vitamin A deficiency (VAD) continues to be one of the most serious health problems in the developing world. The last two decades have seen tremendous improvements in the treatment of VAD, and it has been virtually eliminated among specific sectors of the population in many countries. The number of countries achieving vitamin A supplementation (VAS) targets nearly doubled between 2003 and 2005. These improvements are due to a combination of four strategies, well-tested and proven to be successful: vitamin A supplementation with capsules, the fortification of food with vitamins and minerals, oral supplements or food additives, and dietary diversification.

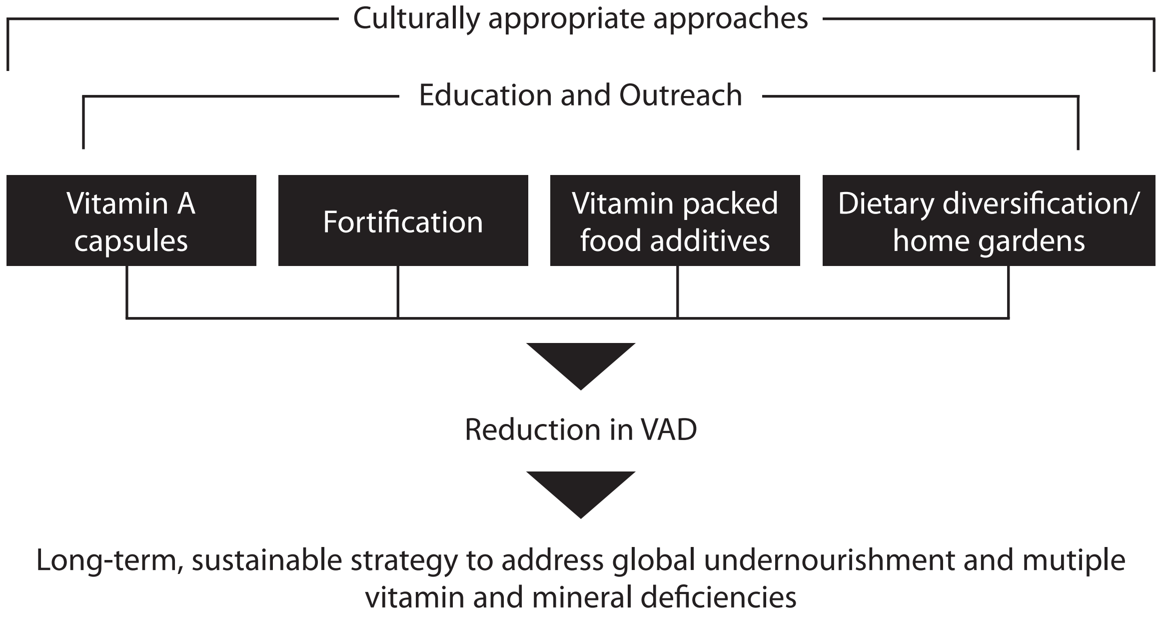

Figure 1. A diverse approach to VAD ensures long-term success.

However, VAD has also been used as a reason to develop so-called 'golden' rice – a variety of rice that has been genetically-engineered (GE) to biosynthesise beta-carotene, a precursor of vitamin A, in the inner edible parts (endosperm) of rice.

Greenpeace considers the term 'golden rice' to be a misnomer – calling this rice 'golden' suggests that it is a panacea or miracle cure, which – after 20 years of development, millions of dollars of funding and significant promotion by a number of organisations – it clearly is not.

The marketing of so-called golden rice is often promoted as a solution to VAD in countries where rice is a staple food. This solution is not only ecologically irresponsible – introducing GE rice on the Asian continent, a centre of origin and diversity for rice, has the potential to contaminate invaluable genetic resources for combating future disease in rice varieties – but it also misses the point: **VAD is routinely associated with other nutritional deficiencies**. Thus, programmes that improve the intake of all necessary vitamins and minerals and promote access to a healthy balanced diet are the only truly sustainable solution to the widespread problem of chronic undernourishment.

Addressing VAD: Success Stories – Asia

While Asian countries have made considerable progress in combating VAD in recent years, South Asia remains the most seriously affected region in the world. Nearly half of all VAD and xerophthalmia (extreme dryness of the eyes) cases occur in south and southeast Asia (UNSCN 2004). Efforts to combat VAD in the region are substantial; in 2008, of children under 5 years old, 70% are receiving full VAS in Asia (UNICEF 2009). Foods fortified with vitamin A are available in Malaysia and the Philippines, with some progress towards fortification in the Democratic People's Republic of Korea, Indonesia, Thailand and Vietnam. South Asia is also working toward fortification of oil-based staples such as ghee (UNICEF 2007a).

Despite the work left to be done, successful models for combating VAD in this region are abundant.

Work done by Helen Keller International (HKI) in Bangladesh over the last four decades provides a particularly impressive model for the eradication of VAD. Rural Bangladesh is one of the most undernourished regions of the world, with 46% of children under five underweight and 36% of mothers chronically energy deficient (HKI/IPHN 2006a). Micronutrient deficiencies affect 50% of children and women of reproductive age (HKI/IPHN 2006a). In the early 1990s, HKI began a home gardening project in rural Bangladesh to address VAD. This has since been expanded to a formal Homestead Food Production (HFP) programme to include animal husbandry and consumption of animal products (HKI/IPHN 2006b) on thousands of rural properties, largely managed by women (HKI 2010). HFP and other food-based strategies have increased food security, reduced micronutrient deficiencies and empowered women in Bangladesh (Bushamuka et al. 2005). The wide-ranging benefits of these programmes have included a lowered risk of night blindness in children living in homes with a homestead garden (Talukder et al. 2000) and increases in pro-vitamin A carotenoid intake (de Pee et al. 2007). Following implementation of the HFP programme, Bangladeshi mothers' daily consumption of pro-vitamin A carotenoid from vegetables and fruits increased eightfold, and their children's (aged under 5 years) consumption increased fourfold (Taher et al. 2004). Combined with the availability of vitamin A-fortified wheat flour, VAD and night blindness are no longer at a level to be considered a public health problem in children under 5 in Bangladesh (UNICEF 2007b).

Country	**Bangladesh**	**Philippines**	**Pakistan**
VAD reduction strategy	• Vitamin A capsules • Fortifications • Dietary diversification/ home gardens	• Vitamin A capsules • Fortifications • Vitamin packets/food additives • Dietary diversification/ home gardens	• Vitamin A capsules • Dietary diversification/ home gardens
Success stories	HFP programme shown to reduce night-blindness, dramatically increase pro-vitamin A uptake in mothers and children.	86% of children receive 2 annual VAS doses; holistic approach includes home, school and community food production, micronutrient supplementation, food fortification, food assistance and nutrition education.	Since 2003, incidence of VAD has dropped from between 35% and 48% of children to less than 5%; government programmes are promoting the intake of green vegetables, yogurt and mangos to address multiple micronutrients.
Status	VAD below 5%	VAD below 5%	VAD below 5%
Source(s)	See above paragraph	Barba and Feliciano 2002; UNSCN 2006a	Sher 2003; WHO database 2010; UNICEF 2009; Khan et al. 2006; Panhwar 2005

So-called 'golden' rice: a distraction

So-called 'golden' rice has been under development since 1990 (Potrykus, 2000). However, the first prototype was unveiled only in 2000 (Ye etal. 2000). Once the intention to commercialise the rice was announced, it was accompanied by a strident media campaign asserting that it could save millions of lives: the headline "This rice could save a million kids a year" appeared on the front page of Time magazine (2000). The developers also placed moral pressure on organisations or institutions opposed to the cultivation of GE crops: "The consequences will be millions of unnecessary blind children and Vitamin A deficiency related deaths." (Potrykus, 2001).

In 2004, Syngenta claimed that it had harvested the first field trial of golden rice in the US, in collaboration with Louisiana State University. It is ironic that the reason for this was that "the USA is one of the few countries in the world where field trials with transgenic (GE) plants can be carried out after complying with an acceptable, well-defined set of regulatory requirements" (Golden Rice Project 2008c). In 2006, an experimental rice variety LL601 was found to have contaminated the US rice supply chain (USDA 2006). As the US Department of Agriculture's Animal and Plant Health Inspection Service has reported, the LL601 contamination originated from Louisiana State University, the same University responsible for the first field trials of golden rice (USDA APHIS 2007). Thus, the possibility of contamination with this experimental GE rice is very real.

Funding 'golden' rice

Over the last 15 years many organisations have been involved in the funding and development of golden rice. The initial stage of the development was financed by ETH Zurich, the Rockefeller Foundation, the Biotech-Programme of the European Union (as part of the Carotene Plus project) and by the Swiss National Science Foundation to a total of $2.6million US dollars (ETH 2004).

Currently, the funding of the so-called 'golden' rice is often channelled through the International Page Rice Research Institute (IRRI), which has been critical in the development of the rice. The idea to develop 'golden' rice came from a discussion at IRRI in 1984 and to this day IRRI is also the base of the Golden Rice Network (IRRI 2009c).

Beyond 'golden' rice, IRRI is researching the development of a number of other GE rice varieties. Most of the funds for these projects are provided by the Bill & Melinda Gates Foundation. In fact in total the Foundation has provided at least 71% of the funds available to current GE projects at IRRI (Table 3). These GE rice projects include traits for:

- drought, heat, and salinity tolerance;
- increased photosynthetic capacity to improve yield and enable more efficient water and nitrogen fertiliser use (C_4 rice); and
- increased nutritional value of the grain, including improved protein quality, and higher iron content (IRRI 2010b).

Table 3. Major IRRI grants received related to projects that include research on GE plants since 2008 (IRRI 2009, 2010c). All values in $1,000 US dollars. Grants likely related to golden rice are highlighted in grey.

Donor	Grant period	Total grant	2018 expenditure	Previous years expenditure	Project
Gates Foundation	15/10/08 – 31/10/11	11,017	11,017	–	Creating the Second Green Revolution by Supercharging Photosynthesis: C_4-rice
Gates Foundation	01/12/08 – 31/11/11	19,954	19,954	–	The Cereal Systems Initiative for South Asia (CSISA)
China	11/01/08 – 31/10/11	4,633	4,633	–	"Green Super Rice" for the Resource-Poor of Africa and Asia
Albert-Ludwig's University of Freiburg	28/09/05 – 27/09/10	1,213	1,213	306	Engineering Rice for High Beta-Carotene, Vitamin E and Enhanced Iron and Zinc Bioavailability
HarvestPlus	01/01/03 – 31/12/08	2,203	2,203	1,664	Biofortified Crops for Improved Human Nutrition
HarvestPlus	2010 – ?	n/a	n/a	n/a	Equipment support to the Workplan "Development of Golden Rice for Philippines, Bangladesh, and Eastern India"
USA (USAID)	01/01/05 – 31/12/09	385	385	59	The Development of Adapted Germplasm for India with High Levels of Pro Vitamin-A Carotenoids
Rockefeller Foundation	1/1/2009 – 31/12/2012	4,000	4,000	n/a	Golden Rice Product Development and Deployment

Conclusions

There is ample evidence that the so-called 'golden' rice is a misguided answer to vitamin A deficiency and malnutrition that will have minimal impact while costing millions of dollars. Instead, those funds would be more wisely invested in successful VAD treatment programmes, already tried and tested in many countries. By looking at the root causes of vitamin A deficiency, projects such as Homestead Food Production have tackled not only VAD, but also other vitamin and mineral deficiencies in the process. Those genuinely concerned with the eradication of VAD face a choice; devote additional resources to untested, costly experiments which stand to endanger the diversity of rice genetic resources, or scale up existing and proven solutions, without any risk of genetic contamination.

Greenpeace promotes ecological farming that ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity, and does not contaminate the environment with chemical inputs or genetic engineering.

Source: Greenpeace (http://www.greenpeace.org)

Article 3

An overview of agriculture, nutrition and fortification, supplementation and biofortification: Golden Rice as an example for enhancing micronutrient intake

Written by: Adrian Dubock, 6 October, 2017

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Abstract

The world's growing population and limited land resources require high intensity of food production. Human nutrition needs both macronutrients and micronutrients. One way of providing micronutrients in staple crops of the poor is biofortification, through plant breeding. All methods of plant breeding are acceptable and safe, and some methods can deliver micronutrients not achievable by other methods. Vitamin A deficiency is responsible for around 4500 preventable child deaths daily, and Golden Rice, biofortified with provitamin A, has proven potential as a costless intervention where rice is the staple crop. Attitudes to GMO crops, after two decades, appear to be changing, which is expected to benefit humankind and the environment.

Keywords: Food security, Biofortification, Vitamin A deficiency, GMO crops, Golden Rice, Greenpeace

Human population, agriculture and food production

Around 71% of the world's surface is covered by water, which contributes only 1% of human food. Less than 20% of the land area is suitable for agriculture. So less than 6% of the world's surface must produce the food humans need [1]. The human population has more than doubled in the last 50 years from 3.5billion to 7.5billion today and will reach almost 10billion people in the next 50 years [2].

For 12,000 years, humans have been continuously breeding crops for increased yield: mostly carbohydrates, an excellent human energy source. The trend to more intensive production by fewer people has accelerated over the past 150 years with science and innovation driving the change: synthetic fertilisers, herbicides, fungicides and insecticides, plant breeding techniques, mechanisation and irrigation, as well as since the late 1990s the incorporation, through transgenesis – resulting in "GMO crops" – of genetic traits. Agriculture has the biggest negative impact on biodiversity of cultivated land. And yet intensive agriculture is the kindest for maintenance of global biodiversity by protection of wild lands from food production. In the industrialised countries, for most of the time following WWII, there has been an increasing ubiquity, often imported, of plentiful and nutritious food at low prices, around 10% of family income. Larger farm units lead to economies of scale in production. Only around 2% of the population are farmers and produce the food for all. Ninety-eight percent of the population have little understanding of agriculture or the technology involved, and as food is an emotional subject, it is easy to stimulate fear of food production systems. In the non-industrialised countries, in contrast, food production is often under-resourced, requiring in some countries 60–70% of the population to be farmers. Very small farms are the norm. Land tenure and market access are two of many issues which exacerbate the difficulties in food production. Farming is not a high-status occupation, and there is a continuing migration of labour from the land in the expectation of a better life in cities. For those left behind, often the old, the work becomes ever more demanding, and less productive, with a tendency to increasing poverty. With inefficient production and poverty, food takes up a huge proportion (perhaps 50%) of available family income in these countries.

Following World War II in many countries, there were food shortages. Food rationing in the UK only ceased in July 1954. From the 1940s, the international nutritional focus was on macronutrient sufficiency. Human population was starting to increase rapidly. Nevertheless, in all regions of the world except Africa, per-capita food production increased for the four decades following the 1960s Green Revolution [3].

Per-capita food production, 1961 and various years

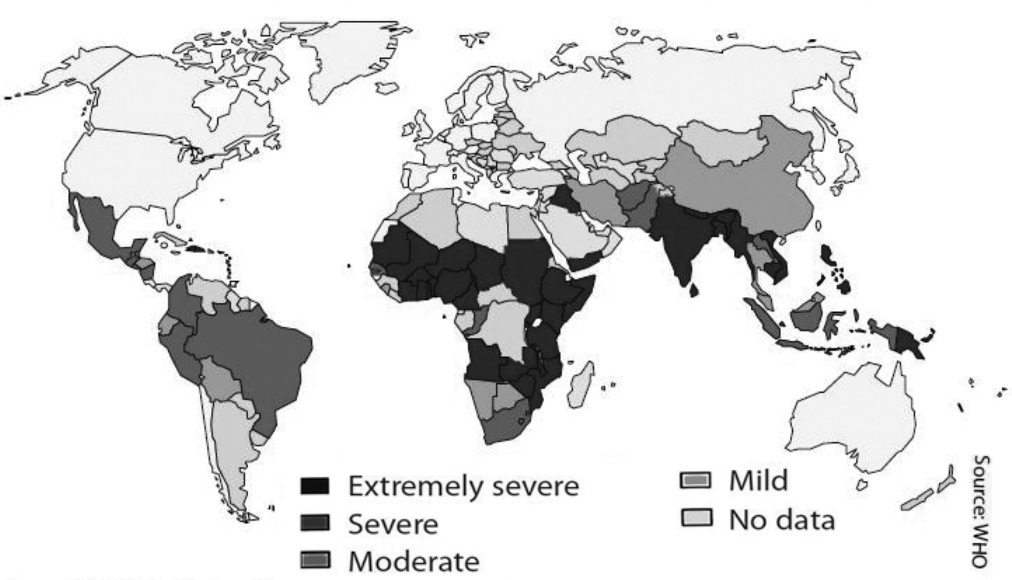
Continent	1961	1971	1981	1991	2001
Africa	100	103	94	90	90
Asia	100	104	114	134	173
South America	100	100	115	118	144
World	100	107	112	115	126

"According to the Food Security Index 2016, developed western countries hold the highest levels of food security while sub-Saharan African countries are at the bottom of the rankings. Germany and France, which have opted out of cultivating GMO crops – both ranked 6/113; in contrast, Kenya ranked 83 and Mozambique 108". "…why should Africa be prohibited from growing the most technologically advanced and sustainable crops?" "[African] Farmers need and want choices, not European-imposed restrictions" [8]. Especially as Africa's population is forecast to experience by far the largest percentage change (>100%) of all global regions between 2015 and 2050 [9]. Poverty is often associated with very limited dietary diversity. Carbohydrate-rich grains are an important energy source. The other macronutrients, fats and proteins, are important too. However, humans also need micronutrients – minerals such as iodine, iron and zinc and vitamins such as vitamins A, C, D, B_1 and B_3 for healthy development and life. Micronutrients exist as either minerals, taken up from the soil and accumulated by plants, or vitamins that are synthesised either by plants or by animals. Energy-rich grains are extremely important, but without dietary diversity are not sufficient for a healthy life [5]. In industrialised countries, dietary diversity includes not only plant products, but also animal products, and populations with such a varied diet generally benefit from sufficiency of both macronutrients and micronutrients. Often poor people in developing countries have very limited access to animal products, for economic or other reasons.

Vitamin A deficiency

Human populations deficient in the minerals such as iron and zinc, and in vitamin A, suffer from a variety of serious developmental and public health issues, and these deficiencies are more widespread globally than other important micronutrient deficiencies [5]. Vitamin A deficiency, VAD, which mostly affects children less than 5 years old, and to a lesser extent their mothers, is widespread and well documented by the World Health Organisation [18].

Public health importance of vitamin A deficiency, by country



Source: WHO data. Redrawn by and produced courtesy Banson

By the 1990s, VAD was known as the major cause of childhood blindness globally, with about 500,000 cases annually, of which about two-thirds die if not treated [19]. As a result, for more than a quarter of a century, vitamin A deficiency (VAD) has been recognised by the United Nations as a significant public health problem.

What was not known clearly in the 1990s was that VAD also suppresses the human immune system: VAD is "a nutritionally acquired immune deficiency syndrome" [12]. Eyesight problems and immune deficiency-related deaths are two different morbidities of vitamin A deficiency. Most who die as a result of VAD do not become blind first. Increased susceptibility to disease as a result of VAD results in the majority of the millions of preventable < 5-year-old child deaths, mainly among children, annually [23, 24].

A universally available source of vitamin A could save 23–34% of all deaths of children under 5 years old globally and reduce measles mortality by up to 50% [23, 26]. As the UN regularly measures and publishes global all-cause child mortality [27, 28], the importance of VAD mortality can be stated compared with other public health mortality causes especially important in the countries where poverty is widespread:

Global mortality from important public health diseases

Global mortality (millions)	**2010**	**2014**
Vitamin A deficiency	1.9–2.8	1.4–2.1
HIV / AIDS	1.8	1.2
Tuberculosis	1.4	1.1
Malaria	0.7	0.6

Data sources: For 2010 data [24]; for 2014 data [23, 29–32]

Why is combatting VAD such a challenge? Only animals, including human beings, synthesise vitamin A. No plants contain vitamin A. The only direct sources of vitamin A itself are animal products: liver, butter, milk and eggs are excellent sources. Animals and humans synthesise vitamin A from carotenoid chemicals naturally occurring in coloured fruits, vegetables and leaves. Beta carotene (β-carotene) is a particularly important provitamin A carotenoid found in all coloured plant foods. In industrialised countries, VAD is not a significant problem because a varied diet includes animal products and various sources of provitamin A carotenoids, and also there is widespread fortification of food products together with the use of vitamin supplements by newborns and pregnant and lactating women. In the poorer sections of developing countries, food sources that are most valuable in terms of micronutrients – animal products including milk, eggs, butter, liver and fish – are usually more expensive and "beyond the reach of poor families" [12].

Biofortification and Golden Rice

There are several strategies for addressing micronutrient deficiencies caused by insufficient dietary diversity. Industrial fortification (e.g. adding iodine to salt, vitamins A and D to margarine, fluoride to toothpaste, folic acid to flour) has been used successfully to ensure sufficiency of micronutrients to populations. Supplementation involves provision and consumption of tablets, syrup or capsules containing micronutrients and has also been employed in both industrialised and developing countries. Both fortification and supplementation, however, require some level of manufacturing and/or distribution infrastructure, and the micronutrients need to be paid for, even if they are free to the consumer. As a result, the most marginalised, and the neediest may not benefit.

In 2000, two German professors, Ingo Potrykus and Peter Beyer, proved that they could modify the genome of white rice to produce beta-carotene, the precursor which the human body uses as a source to make vitamin A [42, 43]. They then donated the technology involved in the creation of Golden Rice to benefit the disadvantaged in the developing world, mindful particularly of the intractable vitamin A deficiency problems in India and other countries of Asia. Their interest in the humanitarian use of their technology was not inconsistent with commercial interest (from 2000 to 2004) for industrialised countries for the same technology by the company Syngenta. The first licensee of the Golden Rice inventors, in 2001, was the International Rice Research Institute (IRRI) a not-for-profit institute established in the Philippines. All the other 15 Golden Rice licensees are rice laboratories of national governments. "Golden Rice" is the first purposefully created biofortified food. It is a rice that synthesises and accumulates β-carotene during seed maturation [42]. Following normal harvesting, grain polishing, storage, cooking and consumption, the human body efficiently converts the β-carotene in Golden Rice to vitamin A [44]: "In summary, the high bioconversion efficiency of Golden Rice beta-carotene to vitamin A shows that this rice can be used as a source of vitamin A. Golden Rice may be as useful as a source of preformed vitamin A from vitamin A capsules, eggs or milk to overcome VAD in rice-consuming populations" [24]. Calculations suggest that 40 g of dry Golden Rice, after normal harvest, polishing, storage and cooking, when consumed daily, will save the life and sight of people who would otherwise be vitamin A deficient [24].

Plant breeding and safety

Traditionally improvements to plants have been achieved by crossing plants of the same species, observing the plants which arise from the random mixing of genes which occurs in the reproductive process, and selecting the individual plants with the most useful characteristics for the next round of cross-breeding. Over 12,000 years, the approach has gradually improved domesticated plants. Initially, it was carried out by the early farmers, and since the latter part of the 1800s by more specialised plant breeders, who increasingly combine careful observation and record keeping with biological understanding. Contrary to other claims to the accolade, it is probably plant breeding which is "the oldest profession". When the inventors of Golden Rice started out, they considered four different scientific approaches [33]. Because there was no rice variety which exhibited yellow grains, there was no variability to exploit through the conventional plant crossing route, and it was unlikely to be effective to mutagenise rice seeds or plants. But they knew that genes inducing a yellow colour were present in some easily obtainable plant tissues. By selecting the genes giving the yellow colour to daffodil (narcissi) flowers, and introducing them to the rice genome in a way which allowed gene (and therefore colour) expression in rice seed, they were able to create the prototype Golden Rice [42, 43]. Subsequently, the Syngenta scientists took other genes known to be associated with beta-carotene synthesis in seeds, those from maize, and were able to induce synthesis of higher levels of beta-carotene, both in micrograms and in percentage of total carotenoids [49]. It is this latter approach which is the basis of Golden Rice today. From either the daffodil or maize, the genes were combined with the rice genome using the genetic modification technique "transgenesis": so Golden Rice is a "GMO" (genetically modified organism). But only once, in about 2004 for today's Golden Rice: since 2004, for the past 13 years, all subsequent development of Golden Rice has been through "conventional" cross-breeding. Much has been made of the potential differences for safety to man, animals or the environment between conventionally bred crops and GMO crops. These concerns are often conflated and inflated by association with dislike of the commercial behaviour of companies which have been most associated with the introduction of GMO crops. This is unfortunate because the effect is to reduce the ability of non-commercial entities to utilise the power of genetics, so beneficially harnessed in medicine and food processing [33, 60], to benefit food production. Conversely, all independent science-based institutions globally [50–54] have found crops produced by transgenesis to be of no more concern than crops produced by any other method. There are many references, but a particularly clear one comes from the heart of the geography politically most opposed to GMO-technology, the European Commission: "The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than, for example, conventional plant breeding technologies" [51].

Economics

It has been calculated that conservative adoption of Golden Rice in Asian countries would add ~US$6.4 billion to those countries GDP through increased productivity enabled by reduced vitamin A deficiency-induced sickness, and improved eyesight, and ~US$17.4 billion if Golden Rice adoption encouraged adoption of other nutritional traits to rice, through increased productivity [55]. Compared with the cost of other VAD interventions, Golden Rice, fully costed with all development costs, has been calculated to be at a minimum six times cheaper per "disability adjusted life year" saved [33]. This is because all the costs are "up front". The nutritional technology is in the seed, and once adoption by an area's population is assured, very little cost will be involved in project maintenance or refreshment. The seed reproduces itself, and can be replanted, mostly in the localities where it will be consumed to deliver its nutritional benefits – energy and a source of vitamin A. Undue delay in India to making Golden Rice available has cost the Indian economy US$199 m per year for a decade [56]. Combatting micronutrient deficiencies has been judged at all three separate meetings by different panels of Nobel Laureate Economists as part of the Copenhagen Consensus process, as "the best bang for a buck", that is, the most cost-effective way to solve 30 major problems faced by the world [33]. With the donation terms of the Golden Rice inventors making Golden Rice cost no more than white rice to aid agencies, or governments or consumers, the cost-benefit of Golden Rice where rice is the staple and VAD endemic is expected to be magnificent with no need to change any cultural practices, except the adoption of Golden Rice instead of white rice by growers and consumers. Vitamin A capsules, currently costing about US$1.00 billion per year [24], are only recommended for children of 6 months and older [38], as very young children do not consume solid food. The capsules are not recommended for children younger than 6 months due to toxicity concerns from the vitamin A [39], yet these very young children are the most vulnerable to vitamin A deficiency: neonate deaths in 2011 accounted for 43% (increased from 36% in 1990) of all deaths among under 5 year olds [27]. It is anticipated, but so far unproven, that a good source of vitamin A, such as Golden Rice, when part of the staple diet, can improve the mother's vitamin A status, benefiting her health, and simultaneously via the placenta and breast milk increase her baby's resistance to disease.

Anti-GMO-crop political activism

The seminal Ye et al. paper [42], published on 14 January 2000, announced that the teams of Potrykus and Beyer had succeeded in their "proof of concept" research, demonstrating that the genome of white rice could be changed so that it synthesised and accumulated beta-carotene in the endosperm. It was published in the high-impact journal "Science", published in the USA, after the UK published journal "Nature" had rejected it. This was a gentle portend of political opposition to Golden Rice to come: Europe had been vociferously opposing all GMO crops for the previous 3 years. From this beginning, for the last 16 years, there has been an ongoing low level but impactful publicity insurgency against the Golden Rice humanitarian project by anti-GMO activists, punctuated by a few large battles. Many anti-GMO activist organisations have been involved. The most strident and constant has been Greenpeace.

Greenpeace Press Release, 2012. On 8 August 2012, Tang et al. published online the results of research initially planned in 2003 and completed in June 2008. The authors found: "*In summary, the high bioconversion efficiency of Golden Rice b-carotene to vitamin A shows that this rice can be used as a source of vitamin A. Golden Rice may be as useful as a source of preformed vitamin A from vitamin A capsules, eggs or milk to overcome VAD in rice-consuming populations*".

Greenpeace commented 3 weeks later, on 29 August 2012: "*Greenpeace alarmed at US-backed GE food trial on Chinese children*" "*It is incredibly disturbing to think that an American research body used Chinese children as guinea pigs for genetically engineered food,………… The relevance of this study is questionable … Nor does high conversion rate solve all the technical, environmental and ethical issues around Golden Rice*" [60].

Following this Greenpeace Press release, and despite Tufts University finding "*no concerns related to the integrity of the study data, the accuracy of the research results or the safety of the research subjects*" [45], Tang et al. 2012 was retracted by the American Society of Clinical Nutrition in 2015 [62].

Science Editorial commenting on Golden Rice Field Trial destruction, Philippines, 8 August 2013: "*The global scientific community has condemned the wanton destruction of these field trials, gathering thousands of supporting signatures in a matter of days. If ever there was a clear-cut cause for outrage, it is the concerted campaign by Greenpeace and other non-governmental organizations, as well as by individuals, against Golden Rice…………… We, and the thousands of other scientists who have signed the statement of protest, stand together in staunch opposition to the violent destruction of required tests on valuable advances such as Golden Rice that have the potential to save millions of impoverished fellow humans from needless suffering and death.*" [65]

Many activists' initial objections to GMO crops are that they were only for industrialised farmers, in industrialised countries, for multinational profit and with no consumer benefit; that they were dangerous for environmental and human health, and their exploitation involved intellectual property rights which would eventually lead to commercial domination of food production. When it was demonstrated that Golden Rice, a GMO crop, did not conform with this stereotype, first of all the activists tried to prove it could not be effective and then tried to vilify or destroy the research which demonstrated its potential. Finally, after demolition of all their arguments, they claimed that Golden Rice was a "Trojan Horse" being manipulated by its proponents merely as a device to create more valuable commercial opportunities for multinational companies to exploit GMO crops, create new farmer dependencies and remove farmer choice.

Conclusion

The public sector holds the responsibility for public health delivery through biofortification of food security crops. For micronutrient biofortification especially, plant breeders need rapidly to catch up with the 12,000-year head-start of seed breeding for yield. Precision agriculture – including GMO crops – now provides the tools to assist: for macronutrients yield, to adapt yields to climate change and other difficult growing conditions, as well as micronutrients. Most farmers using GMO crops in 2014 – clearly of their free will – did so on small farms in developing countries.

Following submission of regulatory data packages to national authorities, it can be anticipated that Golden Rice will be cleared as safe to humans, animals and the environment and made available to countries and populations which want to incorporate it into their culture of rice cultivation and consumption.

Over time, independent research will be undertaken to measure the effect of Golden Rice's regular consumption on vitamin A status of individuals and populations. And in the longer term, on the effect of Golden Rice's regular consumption on the morbidity and mortality of populations which adopt it as a routine part of the staple diet.

Subsequently, if donors are not too fatigued to pay for the development, other micronutrient traits will be combined with the provitamin A beta-carotene in multi-vitamin and multi-mineral rice. Proof of concept has already been achieved for some, a long time ago for folate, and more recently for iron and zinc.

Individuals in developing countries, following registration of Golden Rice, can manage its adoption as a routine part of agriculture and consumption, themselves, without western philanthropic or aid or non-governmental organisation assistance. The result will be truly dignified and sustainable. And a major contribution to alleviation of the effects of poverty, while other methods continue to be targeted at poverty alleviation itself.

The delay to Golden Rice's development has been principally due to suspicion and political interference continuously experienced since first strongly expressed in 2000. The project should have been where it is today, with the major part of a regulatory package finished, in around 2006, 11 years ago.

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This article has been edited and some references have been removed from the list.

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