ASK-FORCE Contribution No. 6 renewed GM crops produce more yield, the debate behind the statement

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Contributions of colleagues cited in the text
(Wayne Parrott, Christopher Preston and David Tribe)

Contents

1. The Issue: Claiming low yield for GM Crops with manipulated data

1.1. Issue Report Union of Concerned Scientists (UCS) Failure to Yield

The short summary of the press release of the Union of Concerned Scientists (UCS):

"Failure to Yield is the first report to closely evaluate the overall effect genetic engineering has had on crop yields in relation to other agricultural technologies. It reviewed two dozen academic studies of corn and soybeans, the two primary genetically engineered food and feed crops grown in the United States. Based on those studies, the UCS report concluded that genetically engineering herbicide-tolerant soybeans and herbicide-tolerant corn has not increased yields. Insect-resistant corn, meanwhile, has improved yields only marginally. ***The increase in yields for both crops over the last 13 years, the report found, was largely due to traditional breeding or improvements in agricultural practices."*** *(Gurian-Sherman, D, 2009)*

Gurian-Sherman, D. (2009)
Failure to Yield, Evaluating the Performance of Genetically Engineered Crops, Union ot Concerned Scientists pp (Report)
www.ucsusa.org AND http://www.botanischergarten.ch/GM-General/Gurian-Sherman-failure-to-yield-2009.pdf AND
Press conference: http://www.ucsusa.org/food_and_agriculture/science_and_impacts/science/failure-to-yield.html

Comments:

1. The report deals only with two major crops: Maize and soybean, there is no justification for the sweeping conclusions on all GM crops. Other crops like cotton and oilseed rape show a different, more positive picture, it is misleading to restrict the review to two crops and then conclude for all GM crops.
2. GM crops have – at least in the beginning – not been developed to increase yield per se (the second generation of GM soybean will do this. The first GM crop generation has been conceived to efficiently reduce yield losses to weeds and insects - and thus enhance the economic situation of the farmers, *and these promises have been fulfilled properly and with evident success.* UCS misleads the reader by not distinguishing those two views of yield.
3. GM crops have also efficiently reduced herbicide use (or made it possible to shift to environmentally more benign ones) and also they have helped to reduce pesticides. It is misleading by UCS not to mention those facts.
4. GM crops have a proven positive influence on the ecological footprint of intensive high production agriculture (no tillage, better life for non-target insects etc.). It is misleading by the UCS report to camouflage those positive effects under "agricultural practices".

1.2. Issue paper Heinemann on doubts on sustainability of GM crops

Heinemann, J. A., M. Massaro, D. S. Coray, S. Z. Agapito-Tenfen and J. D. Wen (2013), Sustainability and innovation in staple crop production in the US Midwest International Journal of Agricultural Sustainability, pp. 1-18,
http://dx.doi.org/10.1080/14735903.2013.806408 AND http://www.ask-force.org/web/Sustainability/Heinemann-Sustainability-Innovation-20130620.pdf

"An agro-ecosystem is constrained by environmental possibility and social choices, mainly in the form of government policies. To be sustainable, an agro-ecosystem requires production systems that are resilient to natural stressors such as disease, pests, drought, wind and salinity, and to human constructed stressors such as economic cycles and trade barriers. The world is becoming increasingly reliant on concentrated exporting agro-ecosystems for staple crops, and vulnerable to national and local decisions that affect resilience of these production systems. We chronicle the history of the United States staple crop agro-ecosystem of the Midwest region to determine whether sustainability is part of its design, or could be a likely outcome of existing policies particularly on innovation and intellectual property. Relative to other food secure and exporting countries (e.g. Western Europe), the US agro-ecosystem is not exceptional in yields or conservative on environmental impact. This has not been a trade-off for sustainability, as annual fluctuations in maize yield alone dwarf the loss of caloric energy from extreme historic blights. We suggest strategies for innovation that are responsive to more stakeholders and build resilience into industrialized staple crop production.(Heinemann, JA, et al., 2013)

Summary comments of Christopher Preston (Preston Christopher, 20130628)

"Rate of yield increase of corn in US has increased since 1996 compared with prior Rate of yield increase in Western Europe has decreased since 1996, compared with prior. Although none of the rates are significantly different. Rate of yield increase of canola in Canada has increased since 1996 compared with prior. Rate of yield increase in Western Europe has decreased since 1996, compared with prior. The rates are significantly different. Rate of yield increase in Canada prior to 1996, was significantly lower than the others." See details below in Section 15.5.

Comments:

Jack Heinemann, a professor from the University of Christchurch, is well known for his activities worldwide on negative aspects of GM crops. Although he has been many times contradicted, e.g. (Heinemann, JA & Traavik, T, 2004a, Heinemann, JA & Traavik, T, 2004b, Heinemann, JA & Traavik, T, 2005) he continues with his campaign – he has even defended the recent paper of G.E. Séralini (Seralini Gilles-Eric, et al., 20120918) with polemic arguments (Heinemann, J, 20121107) giving seemingly plausible answers to critique, but carefully avoiding the pitfalls related to the use of highly tumor-prone Sprague-Dewey rats in long term experiments, targeted explicitly even by the editor on chief of the journal publishing carelessly the original Séralini paper (Hayes A. Wallace, 20121106)

2. In a response to the UCS report, Prof. Wayne Parrott, an experienced agricultural specialist, summarizes his critique:

Parrott, W. (2009), *An analysis of "Failure to Yield" by Doug Gurian-Sherman, Union of Concerned Scientists, Parrottlab, publ: Wayne Parrott, 19. 4. 2009: 19. 4. 2009, http://www.co.lake.ca.us/Assets/BOS/GE+Crops+Committee/Parrot+Response.pdf*

"The report by the Union of Concerned Scientists rightly differentiates between intrinsic yield (what the crop could produce) and operational yield (what the crop actually produces). The premise of the report is that GM crops are a bad means to achieve global agricultural sustainability simply because they have not affected intrinsic yield. Surprisingly, while the report mentions 'wealth of data on yield under real-world conditions' it fails to use these data. The report focuses on corn and soybean, omitting the extensive data available from cotton and canola. Finally, the report focuses on the US, omitting the results from the rest of world. Collectively, these omissions in the UCS report serve to distort the actual situation."

Wayne Parrott is also cited in (Sheridan, C, 2009) with the following statement:

"A crop doesn't have to have a higher yield to justify its existence, profitability is farmers' primary concern, and factors such as reduced input requirements, easier crop management and improved performance all feed into farmers' decision-making processes."

3. Positive development of operational yield based on hard data Brookes and Barfoot, ISAAA report: The real impacts 1996-2006 based on sound statistics (Brookes, G & Barfoot, P, 2008):

Brookes, G. & Barfoot, P. (2008)
Biotech crops: the real impacts 1996-2006 - yields, summary and full report, PG Economics Ltd. pp 4 and 13 Wessex Barn Frampton Dorchester Dorset DT2 9NB UK (Report)
http://www.pgeconomics.co.uk/pdf/GM_Crop_yield_summary.pdf AND full report:
http://www.botanischergarten.ch/Yield/Brookes-Yield-GM-crops-2008.pdf

These authors also respond harshly and do not hesitate to rebut the UCS report in the main arguments (Brookes, G & Barfoot, P, 2009)

Brookes, G. & Barfoot, P. (2009)
Union of Concerned Scientists report on GM crop performance is misleading, PG Economics Ltd. Briefing note 17. April 2009 pp 6 Wessex Barn Frampton Dorchester Dorset DT2 9NB UK (Report)
http://www.pgeconomics.co.uk/pdf/UCSresponseapr2009.pdf

The full citation of the main arguments:

"PG Economics concludes that the UCS report title does not reflect the report findings. Fundamentally, the UCS report confirms that GM crop technology has improved crop yields and productivity in the US.

PG Economics has, below, identified a number of deficiencies in the UCS report and presented a summary of the key real impacts of GM technology. For those reviewing the UCS report, it:

"Misleads by examining issues from a narrow geographical perspective: Given GM crops have been grown commercially worldwide on a large scale since 1996, any appropriate evaluation of GM trait performance should be undertaken from a global perspective, rather than the US-only perspective adopted by the UCS. It is in developing countries where GM technology has delivered the highest positive impacts on operational yield (eg, corn in the Philippines, cotton in India) and facilitated the wider use of second cropping in a season (eg, soybeans following wheat in Argentina)

Misleads by examining issues from a narrow crop perspective. The UCS report focuses only on soybeans and corn, yet ignores the two other crops in which GM traits are widely used; cotton and canola. GM trait use in these crops has resulted in higher operational yields for most users, increased production and improved standards of living for those farmers using the technology (including US farmers). For example, the average operational yield impact of GM insect resistant (GM IR) cotton technology

(1996-2006) has been +11.1% across all global users• Is inconsistent: the UCS document claims in the executive summary that 'GE (genetic engineering) has done little to increase overall yields. The headline to the release also says 'failure to yield', yet the detailed content of the report shows the opposite and subsequently acknowledges that GM ***insect resistant corn has increased (operational) yields*** *in the US. The UCS report also states that 'now that transgenic crops have been grown in the US for more than a decade, there is a wealth of data on yield under real world conditions'. This gives the reader the impression that the paper is drawing on such research to come to its conclusions. Yet the vast majority of references cited in the report are of crop trials, not studies of real world experiences of commercial farmers using GM technology*

Makes inappropriate use of data. The UCS discusses the importance of increasing food production to feed a growing world population and especially the importance of improving agricultural productivity in developing countries. However, the vast majority of the data and studies drawn on do not examine agricultural productivity issues and the use of GM technology in developing countries but are almost all drawn from the US. The UCS also claims that public resources should be re-directed from GM technology research to low input/organic research. However, no data on the relative expenditures of public funds on each of these categories of research and no analysis of any benefits of such a change are presented."(Brookes, G & Barfoot, P, 2009)

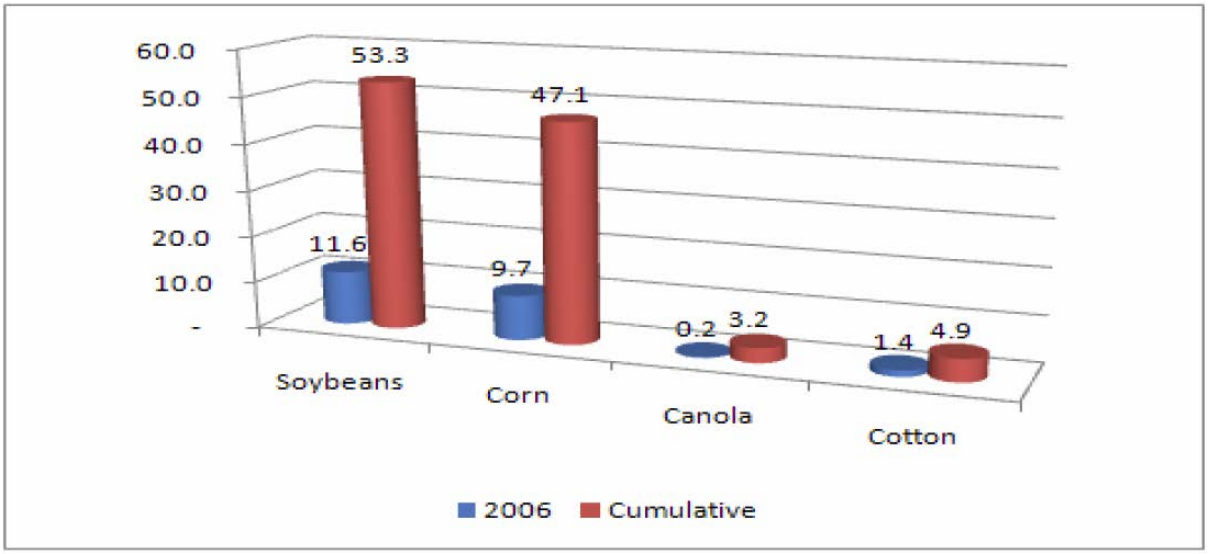


Fig. 1 Additional crop production arising from positive yield effects of biotech traits 1996-2006 (million tonnes) From (Brookes, G & Barfoot, P, 2009)

4. The classic report of 10 years of positive experience from Argentina

10 years of positive experience in Argentina as one of the examples, the data speak for themselves

(Trigo, E & Cap, EJ, 2006)

Ten Years of Genetically Modified Crops in Argentine Agriculture ArgenBio pp 52 Buenos Aires (Report)

http://www.botanischergarten.ch/Argentina/Trigo-10years-Argentina-2007.pdf

From the remarkably balanced conclusions:

"All of these aspects, when taken together, highlight the fact that the first decade of GM crops in argentine agriculture has been a period of large benefits, not only for the agricultural sector, but for the economy as a whole. By now it has become clear that this process has not been one free of both costs and uncertainties, issues that remain open and should be addressed and widely debated from now on. On the other hand, it would have been surprising if a transformation process of the magnitude of the one above described did not have consequences of this nature. The tremendous expansion of the soybean crop has lead to a strong repositioning of agriculture within both the economy and the foreign trade of the country, which has raised concerns about the possible negative impacts of the "soyafication" process, on the one hand, due to the excessive dependence of exports on one single commodity and, on the other, due to its implications associated with the future fertility of the country's soils and the *potential detrimental effects of the crop expansion on fragile ecosystems. These concerns, as well as others that have not been addressed in the document, like, for instance, the future evolution of the international context for this type of technologies, are totally legitimate, but they should not be considered as a demerit of the clearly positive balance of the first decade of GM crops in Argentina. Nevertheless,* *they do emphasize the need for a debate that should take place, on ways to, both, optimize the potential of new innovations in this field, which seems to be growing on a daily basis, and limit the potential negative effects that they might cause. It is worth noting that a realistic look at the new technologies that might be forthcoming, leads to the conclusion that it is very unlikely that one like the case of herbicide-tolerant soybeans will be available in the near future. " (Trigo, E & Cap, EJ, 2006).*

5. Millions of farmers cannot be wrong as shown by the steady increase of the cultivation acreage worldwide, two briefing examples from ISAAA 2009 and 2012.

"Since the beginning of the cultivation of GM crops we have a steady increase of the acreage. And since still the farmers are the main decision-makers on what they want to produce, this development cannot be diminished to false arguments of seed companies pressuring the farmers." See slide collection in citation link below.

(James, C, 2009)
Global Status of Commercialized Biotech/GM Crops: 2008, Brief 39, Executive Summary, Vol. Brief 39, pp. 20. ISAAA
http://www.botanischergarten.ch/ISAAA/ISAAA-Briefs-39-Executive-Summary.pdf AND
http://www.botanischergarten.ch/ISAAA/Brief39Slides-2008.pdf

"As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more hectares of biotech crops in 2008, the thirteenth year of commercialization. Progress was made on several important fronts in 2008 with: significant increases in hectarage of biotech crops; increases in both the number of countries and farmers planting biotech crops globally; substantial progress in Africa, where the challenges are greatest; increased adoption of stacked traits and the introduction of a new biotech crop. These are very important developments given that biotech crops can contribute to some of the major challenges facing global society, including: food security, high price of food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change. Number of countries planting biotech crops soars to 25 – a historical milestone – a new wave of adoption of biotech crops is contributing to a broad-based and continuing hectarage growth of biotech crops globally." (James, C, 2009).

James Clive (2012), ISAAA Brief 44-2012: Executive Summary Briefs ISAAA, 44, pp. 18, http://www.isaaa.org/resources/publications/briefs/44/executivesummary/default.asp AND http://www.ask-force.org/web/ISAAA/James-Brief-44-Executive-Summary-en-2012.pdf AND http://www.ask-force.org/web/ISAAA/James-Brief44slides-2012.pdf

Authors note
Global totals of millions of hectares planted with biotech crops have been rounded off to the nearest million and similarly, subtotals to the nearest 100,000 hectares, using both < and > characters; hence in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates that do not always add up exactly to 100% because of rounding off. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The biotech crop areas reported in this publication are planted, not necessarily harvested hectarage in the year stated. Thus, for example, the 2012 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2012 and harvested in the first quarter of 2013 with some countries like the Philippines having more than one season per year. Thus, for countries of the Southern hemisphere, such as Brazil, Argentina and South Africa the estimates are projections, and thus are always subject to change due to weather, which may increase or decrease actual planted hectares before the end of the planting season when this Brief has to go to press. For Brazil, the winter maize crop (safrinha) planted in the last week of December 2012 and more intensively through January and February 2013 is classified as a 2012 crop in this Brief consistent with a policy which uses the first date of planting to determine the crop year. ISAAA is a not-for-profit organization, sponsored by public and private sector organizations. All biotech

crops hectare estimates reported in all ISAAA publications are only counted once, irrespective of how many traits are incorporated in the crops. Details of the references listed in the Executive Summary are found in the full Brief 44. (James Clive, 2012)

6. IFPRI, a CGIAR – affiliated international organization, published in 2009 a positive balance on the economic side of GM crops:

Smale, M., Zambrano, P., Gruere, G., Falck-Zepeda, J., Matuschka, I., Horna, D., Nagarjan, L., Yerramareddy, I., & Jones, H. (2009)
Measuring the economic impacts of transgenic crops in developing agriculture during the first decade : approaches, findings, and future directions. In II. Series: Food policy review ; 10. 125 pp. (eds. IFPRI). IFPRI, Washington. ISBN 978-0-89629-511
http://www.ifpri.org/pubs/fpreview/pv10.pdf
AND http://www.botanischergarten.ch/Yield/Smale-Measuring-Crops-IFPRI-2009.pdf

In the conclusions, although with caveats, they paint a positive picture on the economic importance of GM crops in the developing countries:

"Literature about the economic impact of transgenic crops on farmers is the most extensive among the four topic areas examined; it is also especially informative because almost all of it is ex post. In contrast to ex ante analysis of potential impacts, ex post research documents actual patterns of adoption and impacts. During the first decade of their use by smallholder farmers in developing economies, peer-reviewed research has indicated that, on average, transgenic crops do provide economic advantages for adopting farmers. However, several general caveats are useful to remember when interpreting the findings reported in this initial literature. A number of specific limitations have also been identified in this review. (Smale, M, et al., 2009)

*The **first general caveat** is that only a limited range of transgenic crops has been studied because few have been released in developing countries. Studies of Bt cotton, which has unique economic and agronomic properties, dominate the literature; a few country case studies also dominate the Bt cotton story. Thus we should be careful not to generalize from these experiences to other crop-trait combinations and contexts. Similarly there are relatively few different authors publishing case studies in peer-reviewed international journals, and there is also a wide range of quality among the journals publishing the research.*

*A **second general caveat** is that averages mask considerable variation. The magnitude of the economic advantages varies substantially according to the nature of the cropping season and the geographical location of the study. This would be the case whether or not the seed introduced were transgenic, but the variation is particularly pronounced for IR crops. Variability in crop yields and profitability reflects the reliance of agricultural production on uncertain weather conditions and pest pressures, combined with the heterogeneity of farmers, farming systems, and farm-related institutions. Not all farmers will benefit from IR crops in every cropping season, and this variability is difficult to capture in cross-sectional data collected in single locations.*

*Related **to this caveat is a third**: the length of the period over which adoption and impact are observed can dramatically influence the conclusions drawn by researchers.*

Some success stories are episodic; others are not apparent until years have passed. The impacts we are able to observe also depend on the point along the adoption path that is studied. During the initial years of adoption, it makes sense that researchers have focused on the relative profitability of transgenic crops; if transgenic crops are not advantageous for farmers, they will not adopt them and there will be

no measurable impact of any kind. Only after farmers have planted transgenic crops for a number of years can we assess empirically the effects of adoption on poverty, inequality, health, and the environment." (Smale, M, et al., 2009)

7. Biofortification should also be taken into account when talking about yield

Worldwide, there are dozens of projects working efficiently on bio-fortification, so to say an inner development of crop yield, foremost the well advanced project of the Golden Rice, which will be ready in some years, and this 12 years delay is only due to exaggerated risk assessment regulations and also due to massive opposition of multinational protest corporate organizations. Clearly these are prospects for the near and far future, but considering the fact that all those projects work with novel crops distributed to the poor free of royalties, just as their normal crops, it will be economically and nutritionally of considerable benefit to millions of hungry people.

Al-Babili, S. & Beyer, P. (2005)

Golden Rice - five years on the road - five years to go? Trends in Plant Science, 10, 12, pp 565-573
<Go to ISI>://000234155300005 AND http://www.botanischergarten.ch/Rice/Babili-Golden-Rice-5years-2005.pdf

Through agriculture and local trade, GR is expected to reach the target populations, namely the urban poor and rural populations, particularly those living in remote areas. Here GR is expected to complement more traditional interventions, such as industrial food fortification and supplementation, effectively and sustainably. These interventions rely on centrally processed food items, on the maintenance of adequate distribution logistics and on the specific targeting of deficient populations, and require significant on-going costs to be sustained. GR, in principle, should require little more than the costs of reliable seed production systems for its continued deployment. (Al-Babili, S & Beyer, P, 2005)

Mayer, J.E., Pfeiffer, W.H., & Beyer, P. (2008)

Biofortified crops to alleviate micronutrient malnutrition. Genome studies and Molecular Genetics, edited by Juliette de Meaux and Maarten Koornneef / Plant Biotechnology, edited by Andy Greenland and Jan Leach, 11, 2, pp 166-170
http://www.sciencedirect.com/science/article/B6VS4-4S0R701-1/1/e12139b40ae67abc932e4bdb46069503 AND
http://www.botanischergarten.ch/Rice/Mayer-Biofortified-COPB-2008..pdf

Micronutrient malnutrition affects more than half of the world population, particularly in developing countries. Concerted international and national fortification and supplementation efforts to curb the scourge of micronutrient malnutrition are showing a positive impact, alas without reaching the goals set by international organizations. Bio-fortification, the delivery of micronutrients via micronutrient-dense crops, offers a cost-effective and sustainable approach, complementing these efforts by reaching rural populations. Bio-available micronutrients in the edible parts of staple crops at concentrations high enough to impact on human health can be obtained through breeding, provided that sufficient genetic variation for a given trait exists, or through transgenic approaches. Research and breeding programs are underway to enrich the major food staples in developing countries with the most important micronutrients: iron, pro-vitamin A, zinc and folate. (Mayer, JE, et al., 2008)

Potrykus, I. (2010), Lessons from the Humanitarian Golden Rice' project: regulation prevents development of public good genetically engineered crop products New Biotechnology, 27, 5, pp. 466-472,
http://www.sciencedirect.com/science/article/B8JG4-50K5T51-1/2/469242a5ba1f0f71050d51e2bfd25b38 AND
http://www.ask-force.org/web/Vatican-PAS-Studyweek-Elsevier-publ-20101130/Potrykus-Ingo-Lessons-Humanitarian-Golden-Rice-20101130-publ.pdf

Compared to a non-Genetically Engineered (GE) variety, the deployment of Golden Rice has suffered from a delay of at least ten years. The cause of this delay is exclusively GE-regulation. Considering the potential impact of Golden Rice on the reduction in vitamin A-malnutrition, this delay is responsible for an unjustifiable loss of millions of lives, mostly children and women. GE-regulation is also responsible for the fact that no public institution can deliver a public good GE-product and that thus we have a de facto monopoly in favour of a few potent industries. Considering the forgone benefits from prevented public good GE-products, GE-regulation is responsible for hundreds of millions of lives, all of them, of course, in developing countries. As there is no scientific justification for present GE-regulation, and as it has, so far, not prevented any harm, our society has the urgent responsibility to reconsider present regulation, which is based on an extreme interpretation of the precautionary principle, and change it to science-based regulation on the basis of traits instead of technology. GE-technology has an unprecedented safety record and is far more precise and predictable than any other 'traditional' and unregulated breeding technology. Not to change GE-regulation to a scientific basis is considered by the author 'a crime against humanity'.(Potrykus, I, 2010)

Potrykus, I. (2012), "Golden Rice", a GMO-product for public good, and the consequences of GE-regulation Journal of Plant Biochemistry and Biotechnology, pp. 1-8, http://dx.doi.org/10.1007/s13562-012-0130-5 AND http://www.ask-force.org/web/Golden-Rice/Potrykus-Golden-Rice-GMO-Product-Public-Good-2012.pdf

Abstract Compared to a non - genetically engineered (GE) variety, the deployment of Golden Rice suffers from a delay of more than 10 years. The cause for this delay is GE-regulation.

"Considering the potential impact of Golden Rice on the reduction in vitamin A-malnutrition, this delay is responsible for loss of numerous lives, mostly children and women. GEregulation is also responsible for the fact that public institutions are prevented from delivering a public good GE-product with the consequence that we are faced with a de-facto monopoly in favour of a few potent industries. Considering the forgone benefits from putative public good GE-products, GEregulation can be blamed of being responsible for millions of lives, all of them, of course, in developing countries. As there is no scientific justification for present GE-regulation and as it has, so far, not prevented any harm, our society has the responsibility to reconsider present regulation which is based on the concept of an extreme interpretation of the precautionary principle. It would be justified to change regulation to a science-base and to regulate traits instead of technology. This would make regulation cheaper and faster, without compromising safety. GE-technology has an unprecedented safety record and it is far more precise and predictable than any other "traditional" and unregulated breeding technology." (Potrykus, I, 2012)

Qaim, M., Stein, A.J., & Meenakshi, J.V. (2007)
Economics of biofortification. Agricultural Economics, 37, pp 119-133
<Go to ISI>://WOS:000251940700010 AND http://www.botanischergarten.ch/Biofuel/Qaim-Economics-Biofortification.pdf

"Micronutrient malnutrition is a serious public health problem in many developing countries. Different interventions are currently used, but their overall coverage is relatively limited. Biofortification-that is, breeding staple food crops for higher micronutrient contents-is a new agriculture-based approach, but relatively little is known about its ramifications. Here, the main factors influencing success are discussed and a methodology for economic impact assessment is presented. Ex ante studies from India and other countries suggest that biofortified crops can reduce the problem of micronutrient malnutrition in a cost-effective way, when targeted to specific situations. Further research is needed to corroborate these findings and address certain issues still unresolved. " (Qaim, M, et al., 2007b)

Bouis, H.E. (2007)
The potential of genetically modified food crops to improve human nutrition in developing countries. Journal of Development *Studies, 43, 1, pp 79-96 AND http://www.botanischergarten.ch/Developing/Bouis-Potential-GM-crops-2007.pdf*

"Because of poor dietary quality and consequent widespread micronutrient malnutrition in low income countries, children and their mothers, who have higher requirements for vitamins and minerals due to rapid growth and reproduction respectively, have higher mortality, become sick more often, have their cognitive abilities compromised for a lifetime, and are less productive members of the workforce. Their quality of life and aggregate economic growth are unnecessarily compromised. One way that biotechnology can help to improve the nutrition and health of consumers in developing countries is by increasing the vitamin and mineral content and their

bioavailability in staple foods." (Bouis, HE, 2007).

Pfeiffer, W.H. & McClafferty, B. (2007)
HarvestPlus: Breeding crops for better nutrition. Crop Science, 47, pp S88-S105 *AND*
http://www.botanischergarten.ch/Biofortification/Pfeiffer-HarvestPlus-Nutrition-2007.pdf

"Micronutrient malnutrition, the so-called hidden hunger, affects more than one-half of the world's population, especially women and preschool children in developing countries. Despite past progress in controlling micronutrient decencies through supplementation and food fortification, new approaches are needed to expand the reach of food-based interventions. Bio-fortification, a new approach that relies on conventional plant breeding and modern biotechnology to increase the micronutrient density of staple crops, holds great promise for improving the nutritional status and health of poor populations in both rural and urban areas of the developing world. HarvestPlus, a research program implemented with the international research institutes of the CGIAR, targets a multitude of crops that are a regular part of the staple-based diets of the poor and breeds them to be rich in iron, zinc, and pro-vitamin A. This paper emphasizes the need for interdisciplinary research and addresses the key research issues and methodological considerations for success. The major activities to be undertaken are broadly grouped into research related to nutrition research and impact analysis, and research considerations for delivering biofortifi ed crops to end-users effectively. The paper places particular emphasis on the activities of the plant breeding and genetics component of this multidisciplinary program. The authors argue that for bio-fortification to succeed, product profi les developed by plant breeders must be driven by nutrition research and impact objectives and that nutrition research must understand that the probability of success for bio-fortified crops increases substantially when product concepts consider farmer adoption and, hence, agronomic superiority." (Pfeiffer, WH & McClafferty, B, 2007)

Uncu, A. O., S. Doganlar and A. Frary (2013), Biotechnology for Enhanced Nutritional Quality in Plants Critical Reviews in Plant Sciences, 32, 5, pp. 321-343, <Go to ISI>://WOS:000318154900003 AND http://www.ask-force.org/web/Biofortification/Uncu-Biotechnology-Enhanced-Nutrition-2013.pdf

With almost 870 million people estimated to suffer from chronic hunger worldwide, undernourishment represents a major problem that severely affects people in developing countries. In addition to undernourishment, micronutrient deficiency alone can be a cause of serious illness and death. Large portions of the world population rely on a single, starch-rich crop as their primary energy source and these staple crops are generally not rich sources of micronutrients. As a result, physical and mental health problems related to micronutrient deficiencies are estimated to affect around two billion people worldwide. The situation is expected to get worse in parallel with the expanding world population. Improving the nutritional quality of staple crops seems to be an effective and straightforward solution to the problem. Conventional breeding has long been employed for this purpose but success has been limited to the existing diversity in the gene pool. However, biotechnology enables addition or improvement of any nutrient, even those that are scarce or totally absent in a crop species. In addition, biotechnology introduces speed to the biofortification process compared to conventional breeding. Genetic engineering was successfully employed to improve a wide variety of nutritional traits over the last decade. In the present review, progress toward engineering various types of major and minor constituents for the improvement of plant nutritional quality is discussed.(Uncu, AO, et al., 2013)

Zimmermann, R. & Qaim, M. (2004)
Potential health benefits of Golden Rice: a Philippine case study. Food Policy, 29, 2, pp 147-168 and
http://www.botanischergarten.ch/Rice/Zimmermann-Benefit-Goldenrice.pdf

Golden Rice has been genetically modified to produce beta-carotene in the endosperm of grain. It could improve the vitamin A status of deficient food consumers, especially women and children in developing countries. This paper analyses potential impacts in a Philippine context. Since the technology is still at the stage of R&D, benefits are simulated with a scenario approach. Health effects are quantified using the methodology of disability-adjusted life years (DALYs). Golden Rice will not completely eliminate the problems of vitamin A deficiency, such as blindness or increased mortality. Therefore, it should be seen as a complement rather than a substitute for alternative micronutrient interventions. Yet the technology could bring about significant benefits. Depending on the underlying assumptions, annual health improvements are worth between US$ 16 and 88 million, and rates of return on R&D investments range between 66% and 133%. Due to the uncertainty related to key parameters, these results should be treated as preliminary. (Zimmermann, R & Qaim, M, 2004).

Bai, C., R. M. Twyman, G. Farre, G. Sanahuja, P. Christou, T. Capell and C. Zhu (2011), A golden era-pro-vitamin A enhancement in diverse crops In Vitro Cellular & Developmental Biology-Plant, 47, 2, pp. 205-221, <Go to ISI>://WOS:000290845700002 AND
http://www.ask-force.org/web/Golden-Rice/Bai-Golden-Era-Pro-Vitamin-A-2011.pdf

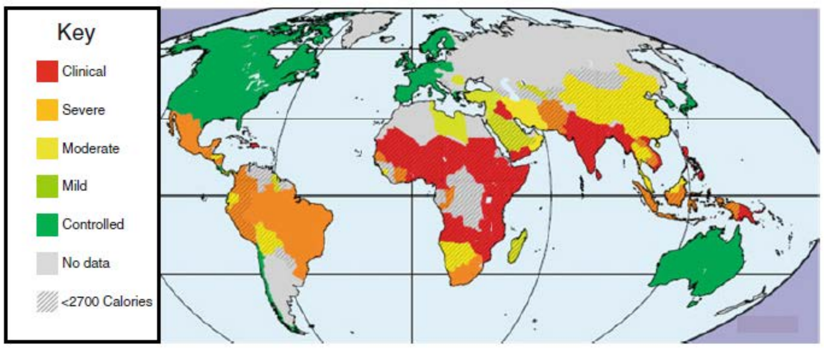


Fig. 2 Impact of vitamin A deficiency around the world (World Health Organization data, 1996). From (Bai, C, et al., 2011)

And some years later

Bassett Thomas J. and Alex Winter-Nelson (2010), World Hunger Atlas edn. University Of Chicago Press; 1 edition IS: ISBN-10: 0226039072
ISBN-13: 978-0226039077 pp. 216, http://www.amazon.com/Atlas-World-Hunger-Thomas-Bassett/dp/0226039072/ref=sr_1_1?s=books&ie=UTF8&qid=1373286929&sr=1-1&keywords=Bassett+%26+Winter-Nelson%2C+2010

The figure from
http://www.ask-force.org/web/Golden-Rice/MIT-Mission-2014-Feeding-the-World-Micronutrients-2013.pdf

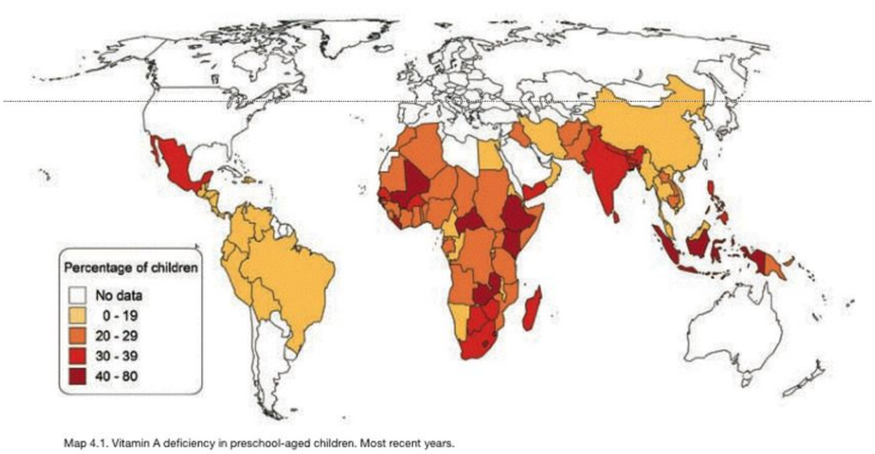


Fig. 3 Map of Vitamin A Deficiency, Source: (Bassett Thomas J. & Alex Winter-Nelson, 2010), World Hunger Atlas figure taken from http://www.ask-force.org/web/Golden-Rice/MIT-Mission-2014-Feeding-the-World-Micronutrients-2013.pdf

A caveat on molecular breeding strategies for biofortification should be taken into account: Concentration control is better than flux control:

Morandini, P. (2013), Control limits for accumulation of plant metabolites: brute force is no substitute for understanding Plant Biotechnology Journal, 11, 2, pp. 253-267, <Go to ISI>://WOS:000314214900009 AND http://www.ask-force.org/web/Biofortification/Morandini-Control-Limits-Accumulation-2010.pdf

Which factors limit metabolite accumulation in plant cells? Are theories on flux control effective at explaining the results? Many biotechnologists cling to the idea that every pathway has a rate limiting enzyme and target such enzymes first in order to modulate fluxes. This often translates into large effects on metabolite concentration, but disappointing small increases in flux. Rate limiting enzymes do exist, but are rare and quite opposite to what predicted by biochemistry. In many cases however, flux control is shared among many enzymes. Flux control and concentration control can (and must) be distinguished and quantified for effective manipulation. Flux control for several building blocks of metabolism is placed on the demand side, and therefore increasing demand can be very successful. Tampering with supply, particularly desensitizing supply enzymes, is usually not very effective, if not dangerous, because supply regulatory mechanisms function to control metabolite homeostasis. Some important, but usually unnoticed, metabolic constraints shape the responses of metabolic systems to manipulation: mass conservation, cellular resource allocation and, most prominently, energy supply, particularly in heterotrophic tissues. The theoretical basis for this view shall be explored with recent examples gathered from the manipulation of several metabolites (vitamins, carotenoids, amino acids, sugars, fatty acids, polyhydroxyalkanoates, fructans and sugar alcohols). Some guiding principles are suggested for an even more successful engineering of plant metabolism. (Morandini, P, 2013).

Karl Haro von Mogels blog “Bio-fortified” offers good arguments and links to other blogs http://www.biofortified.org/2009/04/union-of-concerned-scientists-ge-crops-have-not-decreased-yields/

8. Cotton yield data have increased, the example of India

Cotton in India has not been the subject of the study of UCN of (Gurian-Sherman, D, 2009), this is a case of clear yield increase one should mention here in this context.

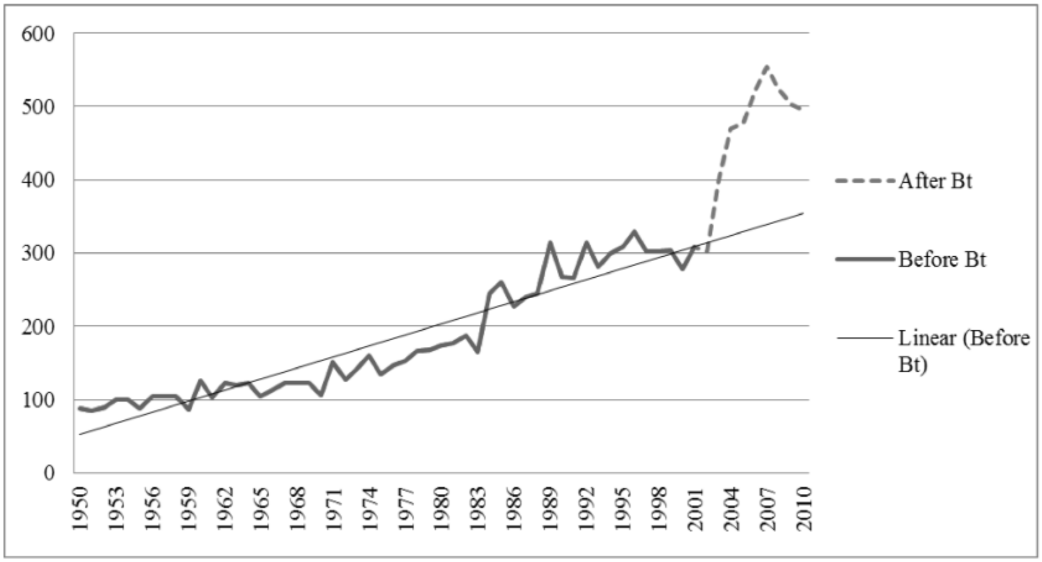
Qaim, M. & Zilberman, D. (2003)
Yield effects of genetically modified crops in developing countries. Science, 299, 5608, pp 900-902
<Go to ISI>://000180830900055 AND http://www.botanischergarten.ch/Cotton/Quaim-Zilberman-Bt-Cotton-2003.pdf

On-farm field trials carried out with Bacillus thuringiensis (Bt) cotton in different states of India show that the technology substantially reduces pest damage and increases yields. The yield gains are much higher than what has been reported for other countries where genetically modified crops were used mostly to replace and enhance chemical pest control. In many developing countries, small-scale farmers especially suffer big pest-related yield losses because of technical and economic constraints. Pest-resistant genetically modified crops can contribute to increased yields and agricultural growth in those situations, as the case of Bt cotton in India demonstrates.” (Qaim, M & Zilberman, D, 2003)

The fact of Indian farmers suicides is a sad tradition, which started way before the introduction of GM cotton, and the mounting yields and reduced highly toxic pesticide use is on the contrary very helpful and increases the quality of the livelihood of the poor farmers, see the balanced analysis of this issue: (Gruere Guillaume P., et al., 2008). See also recent accounts on the Bt cotton situation in India: (Herring, RJ & Rao Chandrasekhara N., 2012, Kathage, J & Qaim, M, 2012, Lu, Y, et al., 2012, Ramasundaram, P & Vennila, S, 2013) and (Kloor Keith, 20130313).

Gruere Guillaume P. and Y. Sun (2012), Measuring the Contribution of Bt Cotton Adoption to India's Cotton Yields Leap, in: IFPRI Discussion Paper 01170, I. E. a. P. T. Division. 28, IFPRI, International Food Policy Research Institute, http://www.ifpri.org/sites/default/files/publications/ifpridp01170.pdf AND http://www.ask-force.org/web/India/Gruere-Measuring-Contribution-Bt-Cotton-India-2012.pdf

Figure 2.1—Average cotton yields in India, 1950–2010



Source: Indian Cotton Advisory Board, obtained from International Cotton Advisory Committee.

Fig. 4 As shown in the Figure, average cotton yields increased steadily over time in India, in an almost linear fashion until 2002, reaching a level close to 300 kilograms per hectare. Starting in 2003, average yields increased dramatically, jumping to more than 500 kilograms per hectare in four years, and then remaining close to that figure in more recent years. The role of Bt cotton appears significant because its adoption started in 2002, but given that the adoption was not fast the first couple of years, perhaps other factors contributed to the average yield growth. From (Gruere Guillaume P. & Sun**, Y, 2012)**

9. Earlier controversy examples on benefits of transgenic corn

(Obrycki, JJ, et al., 2001), claimed in their analysis of transgenic insecticidal corn developed for lepidopteran pests that the potential benefits of crop genetic engineering for insect pest management may not out-weight the potential ecological and economic risks. Together with a large consortium of specialists (Ortman, EE, et al., 2001) answered in the same journal, the main claim again: for answering such questions you absolutely need to obey to *baseline* comparisons.

"Positive and negative impacts of new technologies must be compared with those of existing technologies. All possible impacts of any technology or farming practice are impossible to foresee, but we can focus on known and probable risks. When risks of a technology are characterized as low, based on actual data, then the potential impact should be evaluated proportional to that level of concern. This reasonable approach should reduce the chances of rejecting safe technologies simply because they are new and unfamiliar. Ultimately, the goal is to replace current pest management practices with ones that are more economical and sustainable, as well as environmentally safer. A dynamic equilibrium between benefits and risks will be developed as a result of this ongoing process. Over time, this equilibrium will change as improved practices are developed. In the meantime, if unexpected problems should occur, failsafe mechanisms exist. Any pesticidal technology registered by the EPA can have its registration suspended or canceled when an unreasonable adverse effect is identified. ***The scientific community has examined the risks and benefits of Bt plants more than any other novel agricultural technology developed over the past two decades, as demonstrated by the vast body of literature, scientific discussions, and numerous public meetings facilitated by the EPA, the US Department of Agriculture, and the US***

Food and Drug Administration on this subject. We find the evidence to date supports the appropriate use of Bt corn as one component in the economically and ecologically sound management of lepidopteran corn pests. *" (Ortman, EE, et al., 2001).*

This is just another example, that the UCS study (Gurian-Sherman, D, 2009) did not build on a thorough literature search, since it is not referring to the dispute, for more comments see below in section 11.

10. More Recently published papers on comparative yield performance:

10.1. Contradiction to Gurian-Sherman by C. Sheridan 2009

In a critical account, Nature Biotechnology produced a feature on the report of (Gurian-Sherman, D, 2009):

Sheridan, C. (2009)
Report claims no yield advantage for Bt crops. Nat Biotech, 27, 7, pp 588-589
http://dx.doi.org/10.1038/nbt0709-588 AND http://www.botanischergarten.ch/Yield/Sheridan-UCS-Crop-Failure-NB-2009.pdf

Excerpt from the experts comments:

"Not all public-sector crop scientists contacted by Nature Biotechnology responded to interview requests, ***but those who did were uniformly critical of the report****. "What I object to most about the spin is you've got a false antithesis set up—genetically engineered traits versus breeding. We need both/and, not either/or," says Jonathan Jones, head of the Sainsbury Laboratory at the John Innes Centre in Norwich, UK, and a cofounder of plant biotech firm Mendel Biotechnology, of Hayward, California. He also rejects the view that public sector agriculture research is overly focused on biotech. "If it's true at all, it's not true in Europe. It's a rather parochial view." And he holds anti-GE campaigners responsible for the cost of regulating transgenic crops, which makes it impossible for public-sector organizations to bring their own innovations to the market. "It strengthens the monopoly position of Monsanto et. al. That is an ironic own-goal of the anti-GE campaigners," he says.*

Ken Ostlie, a professor in the Department of Entomology at the University of Minnesota in St. Paul, the Bt toxin genes introduced to corn hybrids are actually benefitting conventional and organic growers indirectly. "These traits are highly effective against the corn borer, and widespread use of Bt corn has actually collapsed the corn borer population," he says. "Everybody's benefitting from that, but you don't see it looking at operational yield benefits at the current time."

"It's the wrong question; it's the wrong analysis; it's the wrong everything," says Wayne Parrott, of the University of Georgia in Athens. "You've got to get past the experimental field trials and look at what's happening on the farm itself." Field trials, he says, are "designed to see what the crop will do under optimal conditions—that's seldom what you'll find on a farm." (Sheridan, C, 2009)

This is just another example, that the UCS study (Gurian-Sherman, D, 2009) did not build on a thorough literature search.

10.2. Large scale survey based on farmers experience with GM crops

In another paper a survey of peer reviewed publications are summarized by (Carpenter, JE, 2010), the main conclusions:

A large scale analysis of farmers experience with GM crops concludes that biotech crops have a positive impact on economic performance and yields for farmers around the world, especially those in developing countries

"Methodology:
An analysis of 49 peer-reviewed publications reporting on farmer surveys that compare yields and other indicators of economic

performance of GM and non-GM crops
The main GM traits evaluated are insect-resistance and herbicide-tolerance
Yield comparison:
74% of yield comparisons of biotech and conventional crops showed positive results for adopters of biotech crops versus non-adopters
When looking to developing countries alone, this number mounts up to 82 percent
The average increases for developing countries range from 16 percent for insect-resistant corn to 30 percent for insect-resistant cotton.
Economic performance:
72 %t of the results are positive when GM crops are compared with their conventional counterparts
For herbicide-tolerant crops, 71% show a positive impact on economic performance
For insect-resistant crops, 74% show a positive impact on economic performance
Influence of GMOs on the environment:
Biotech crops help preserve the environment by facilitating conservation tillage and reducing the number of applications of insecticides" (Carpenter, JE, 2010)

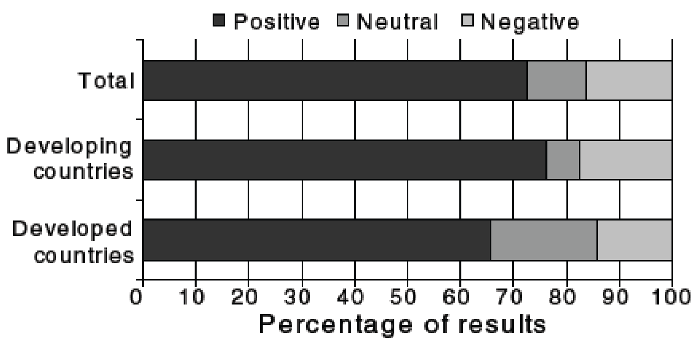


Fig. 5 Results by direction of change in economic performance (GM – conventional). A χ2 test shows a significant difference in the proportion of positive results for developed and developing countries (χ2 = 0.68, df = 1, *P* = 0.41).

10.3. Transgenic crops outcompete conventional crops in risky environment

(Shi Guanming, et al., 2013) demonstrate that commercialized transgenic traits, maize productivity can cope better with yield risks in difficult environment and changing climate.

"In conclusion, our results show how transgenic technology can improve farmers' ability to deal with a risky environment. The availability of this technology seems important given current concerns about the effects of climate change on production uncertainty in agriculture."

Table 1 Mean, variance, skewness and kurtosis of hybrids with transgenes compared with conventional hybrids[a]

Hybrid	Number of observations	Mean yield[b]	Variance of yield[b,c]	Skewness of yield[b]	Kurtosis of yield[b]
Conventional	19,652	186***	709***	–5,770***	793,613***
Glyphosate tolerant (GT)[b]	972	–5.98***	–151***	2,688*	–270,557***
Glufosinate tolerant (GFT)[b]	103	5.76	–121	–5,544	221,296
Bt for European corn borer (ECB)[b]	3,484	6.54***	–61**	1,30 6	–279,710***
Bt for corn rootworm (CRW)[b]	36	–12.22**	–72	9,842*	–322,473**
ECB-CRW[b]	85	3.19	–460***	4,437**	–449,657***
ECB-GT[b]	1,454	3.47***	–260***	3,441***	–411,189***
GT-CRW[b]	166	2.27	–242***	3,816**	–368,791***
ECB-GFT[b]	998	3.13**	–162**	–3,092	–132,537
ECB-CRW-GT[b]	3,215	–1.57**	–336***	3,642***	–432,732***
ECB-GT-GFT[b]	631	2.24	–147**	2,689	–279,236**
ECB-CRW-GFT[b]	206	2.04	–358***	2,738	–390,709***
ECB-GT-CRW-GFT[b]	797	–1.26	–258***	2,642	–364,863***

[a]Simulated transgenic effects are based on estimated coefficients in **Supplementary Table 1** and were evaluated using an arbitrary scenario of maize grown in 2005 in Lancaster, Wisconsin, without irrigation or insecticide application, and with no tillage practice in either fall or spring. All other relevant variables were set at the mean or median. Results comparing yield differences across hybrid types were not affected by these choices, because our analysis was based on pooled data across all sites and was done by evaluating yield differences across hybrid types, controlling for location and time. The standard errors used for the significance tests were bootstrapped. *, $P < 0.1$; **, $P < 0.05$; ***, $P < 0.01$ (*t*-test).

[b]For transgenic hybrids, number of observations, mean yield, variance in yield, skewness of yield and kurtosis of yield are expressed as difference between that of transgenic variety and that of the conventional benchmark.

[c]See **Table 2** for a more intuitive evaluation of estimated effects on variance, skewness and kurtosis.

10.4. Recent patterns of crop yield growth and stagnation

In a summary presenting the present day crop yield situation (Ray, DK, et al., 2012) : The paper is another proof that talking about yields is not solved with a black- and white view, it's a mixed bag with several important vectors like crop trait, environmental conditions and agricultural management:

"In the coming decades, continued population growth, rising meat and dairy consumption and expanding biofuel use will dramatically increase the pressure on global agriculture. Even as we face these future burdens, there have been scattered reports of yield stagnation in the world's major cereal crops, including maize, rice and wheat. Here we study data from B2.5 million census observations across the globe extending over the period 1961–2008. We examined the trends in crop yields for four key global crops: maize, rice, wheat and soybeans. Although yields continue to increase in many areas, we find that across 24–39% of maize-, rice-, wheat- and soybean-growing areas, yields either never improve, stagnate or collapse. ***This result underscores the challenge of meeting increasing global agricultural demands. New investments in underperforming regions, as well as strategies to continue increasing yields in the high-performing areas, are required." (Ray, DK, et al., 2012)*** .

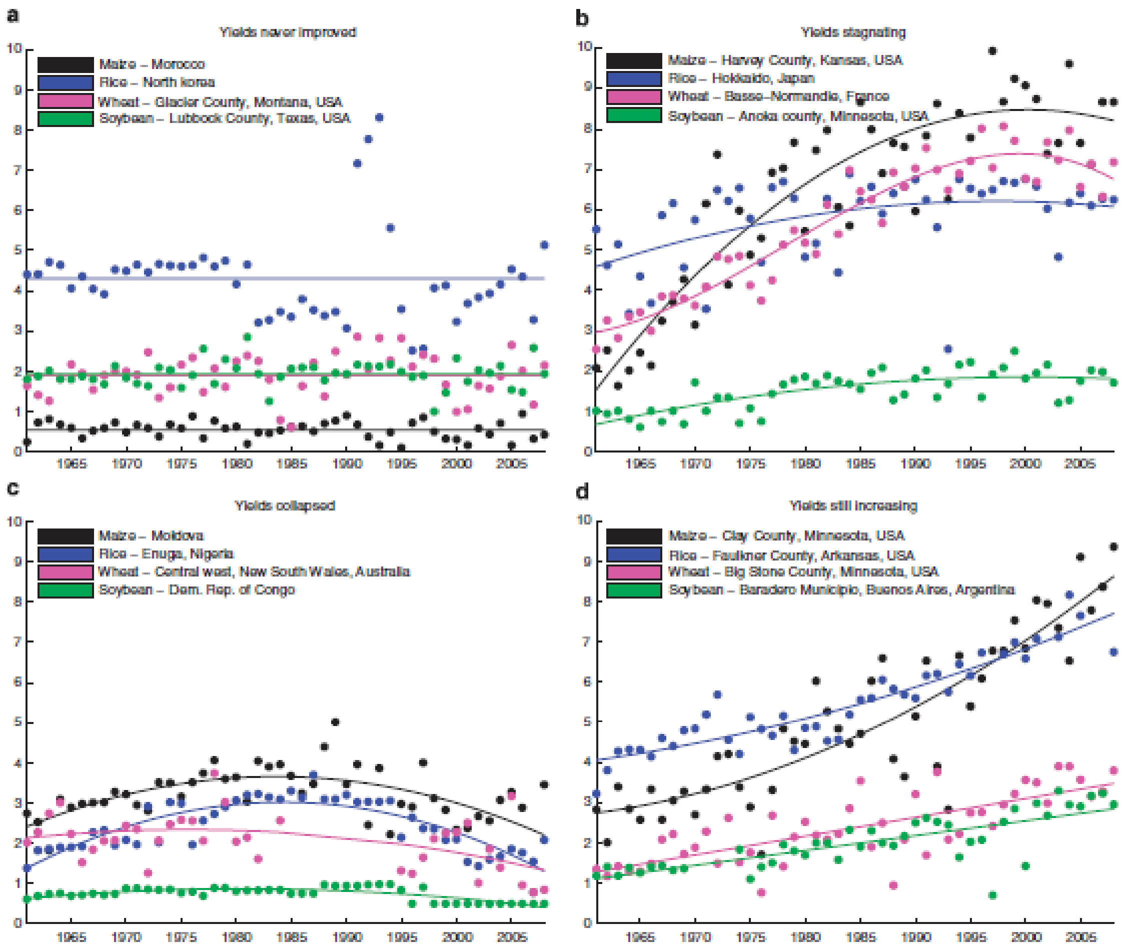


Fig. 6 The solid filled circles in each panel are the observed crop yields from various global locations to serve as illustrative examples. Colour codes indicate the crop. The solid curves are the statistical model fits to the data and similarly colour coded according to the crop type. (a) Yields never improved. (b) Yields stagnating. (c) Yields collapsed. (d) Yields still increasing. From (Ray, DK, et al., 2012)

11.5. Heinemann et al. claiming with manipulated data that modern agriculture does not improve yield

The paper: (Heinemann, JA, et al., 2013) The summary makes several statements on false premises, as explained further down by Christopher Preston:

"An agro-ecosystem is constrained by environmental possibility and social choices, mainly in the form of government policies. To be sustainable, an agro-ecosystem requires production systems that are resilient to natural stressors such as disease, pests, drought, wind and salinity, and to human constructed stressors such as economic cycles and trade barriers. The world is becoming increasingly reliant on concentrated exporting agro-ecosystems for staple crops, and vulnerable to national and local decisions that affect resilience of these production systems. We chronicle the history of the United States staple crop agroecosystem of the Midwest region to determine whether sustainability is part of its design, or could be a likely outcome of existing policies particularly on innovation and intellectual property. ***Relative to other food secure and exporting countries (e.g. Western Europe), the US agroecosystem is not exceptional in yields or conservative on environmental impact. This has not been a trade-off for sustainability, as annual fluctuations in maize yield alone dwarf the loss of caloric energy from extreme historic blights. We suggest strategies for***

innovation that are responsive to more stakeholders and build resilience into industrialized staple crop production.(Heinemann, JA, et al., 2013)

The basis of the above statements is the following graph

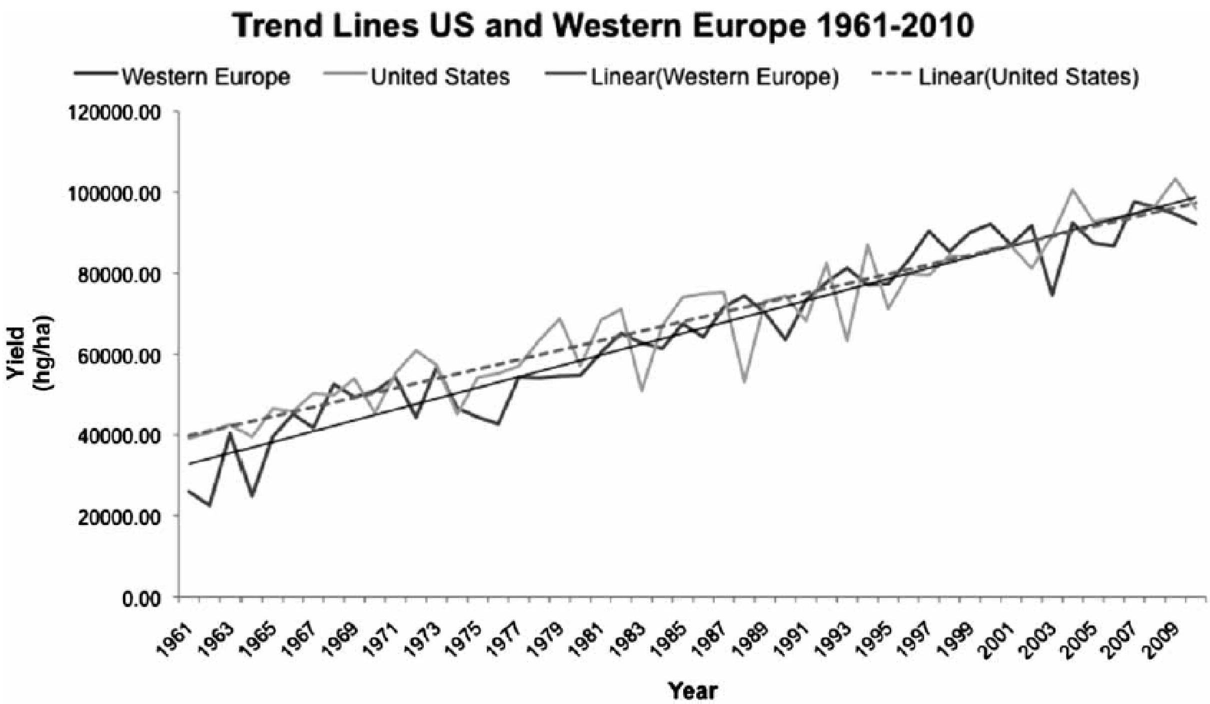
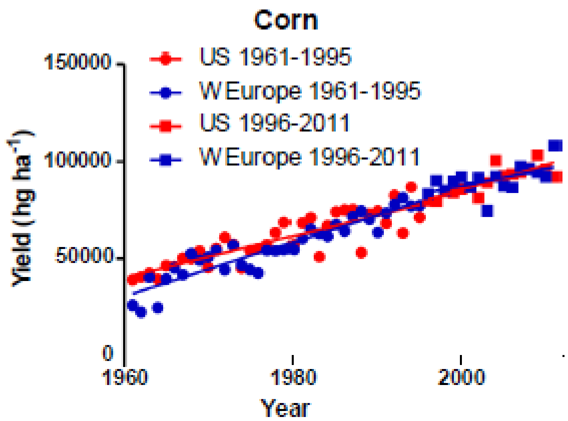


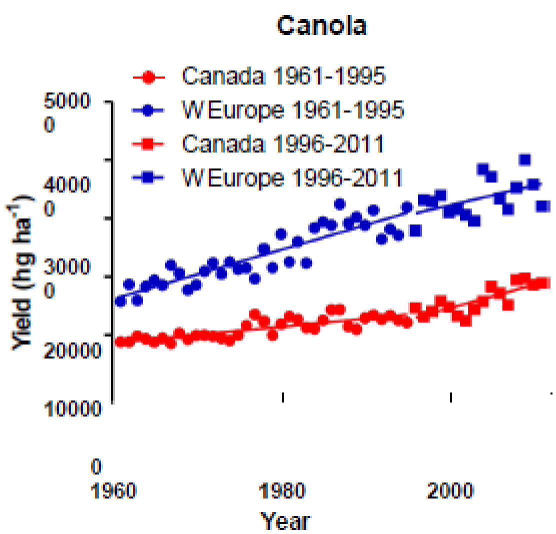
Fig. 7 United States and Western European maize yields and variability over the period 1961–2010. Authors' calculations based on data derived from FAOSTAT (http://faostat3.fao.org/). From (Heinemann, JA, et al., 2013)-

According to a thorough statistical analysis, Christopher Preston refutes the way the data have been presented by Heinemann: In an email from June 28, 2013 (Preston Christopher, 20130628)

"Rate of yield increase of corn in US has increased since 1996 compared with prior.
Rate of yield increase in Western Europe has decreased since 1996, compared with prior.
Although none of the rates are significantly different. Rate of yield increase of canola in Canada has increased since 1996 compared with prior. Rate of yield increase in Western Europe has decreased since 1996, compared with prior. The rates are significantly different. Rate of yield increase in Canada prior to 1996, was significantly lower than the others." (Preston Christopher, 20130628)



Region	Year range	Yield increase (hg/ha/yr)
US	1961-1995	1073
W Europe	1961-1995	1392
US	1996-2011	1273
W Europe	1996-2011	887



Region	Year range	Yield increase (hg/ha/yr)
Canada	1961-1995	138
W Europe	1961-1995	424
Canada	1996-2011	401
W Europe	1996-2011	338

Rate of yield increase of corn in US has increased since 1996 compared with prior.

Rate of yield increase in Western Europe has decreased since 1996, compared with prior.

Although none of the rates are significantly different. Rate of yield increase of canola in Canada has increased since 1996 compared with prior. Rate of yield increase in Western Europe has decreased since 1996, compared with prior. The rates are significantly different. Rate of yield increase in Canada prior to 1996, was significantly lower than the others.

Christopher Preston noticed the major error in the date that GM crops were introduced. The paper states 1986; however, it was in 1996. So he went back to the source data from FAOSTATS and plotted the data from 1961-1995 and then from 1996-2011 and calculated the average yield increase over the two periods.

Email comment of Christopher Preston:
Christopher Preston
christopher.preston@adelaide.edu.au
June 28, 2013

Fig. 8 Comment and recalculation according to FAOstat original data, the graphs show a basically different picture than the original Fig. in Heinemann. (Preston Christopher, 20130628)

Heinemann is a Professor from the Christchurch University and can be seen as a typical “parallel scientist”, definition see (Kuntz Marcel, 201001), producing with persistence negative documentations on GM crops, which are regularly contradicted by better science and arguments based on available hard data.

A comprehensive rebuttal of Heinemann's paper 2013 from a blog called GMO Pundit of David Tribe, here the full text, written jointly with Christopher Preston:

11. More documentations for better yields with transgenic crops

Duvick, D. N. and K. G. Cassman (1999), Post–Green Revolution Trends in Yield Potential of Temperate Maize in the North-Central United States Crop Sci., 39, 6, pp. 1622-1630, https://dl.sciencesocieties.org/publications/cs/abstracts/39/6/1622 AND http://digitalcommons.unl.edu/agronomyfacpub/96 AND http://www.ask-force.org/web/Yield/Duvick-Post-Green-Revolution-Trends-1999.pdf

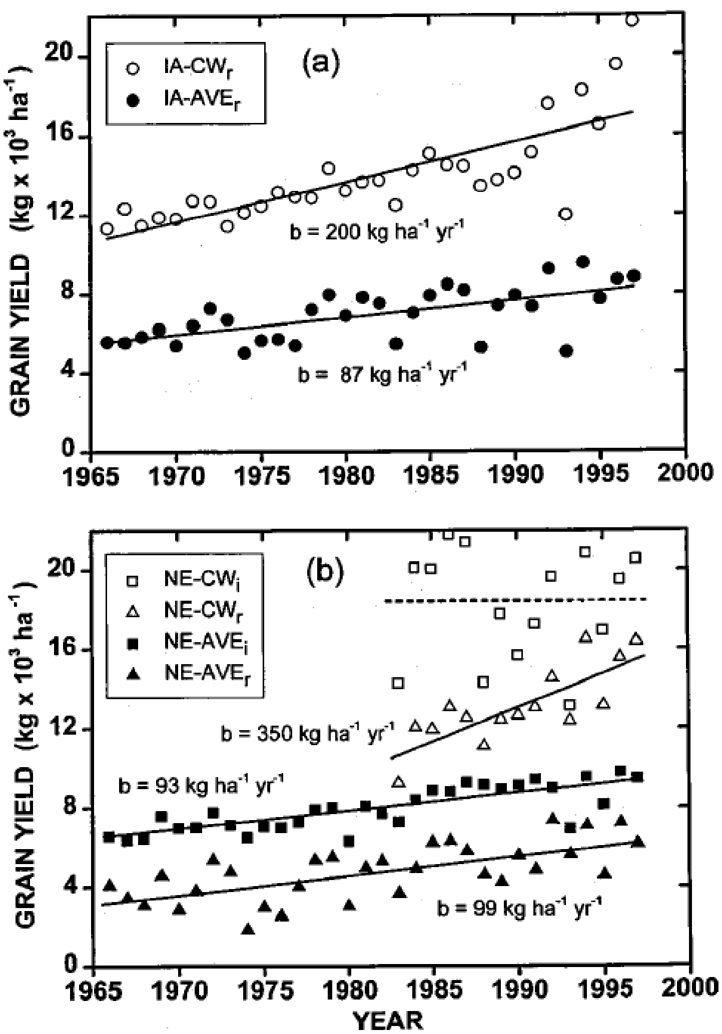


Fig. 9 Despite the Differences in climate and water supply, the rate of increase in average maize yield since 1966 has been remarkably similar in both states and in both rain-fed and irrigated systems. For example, average farm yield has increased linearly at a rate of 87kg per hectare and year, in rain-fed Nebraska systems (fig. 4a) where rainfall is less abundant than in Iowa. Despite this difference in rainfall, the proportion of variance explained by the linear regression of yield vs. year was similar for rain-fed maize in both states. 39% for the average yield in Iowa and 44% in Nebraska (Fig. 4a and 4b), the deviation from regression was much smaller for irrigated maize from Nebraska. R squarre = 0.64, although the rate of increase was similar at 93kg per ha and per year. From (Duvick, DN & Cassman, KG, 1999)

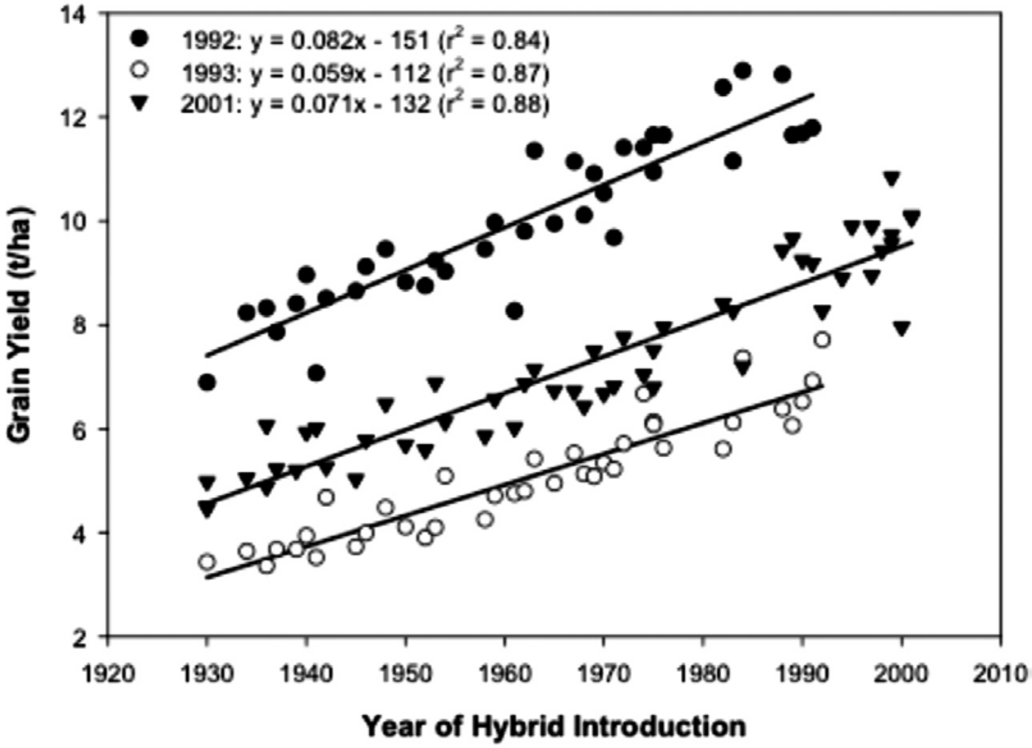


Fig. 10 Grain yield per hybrid regressed on year of hybrid introduction for trials grown in 1992, 1993, and 2001. Growing season was highly favorable in 1992, excessively wet and cold in 1993, and hot and dry in 2001. Yield per hybrid is for the density giving the highest average yield. From (Duvick D. N., et al., 2004) in (Duvick, DN, 2005)

Troyer, A. F. (2006), Adaptedness and heterosis in corn and mule hybrids Crop Science, 46, 2, pp. 528-543, <Go to ISI>://WOS:000235991100003 AND http://www.ask-force.org/web/Yield/Troyer-Adaptedness-Heterosis-2006.pdf

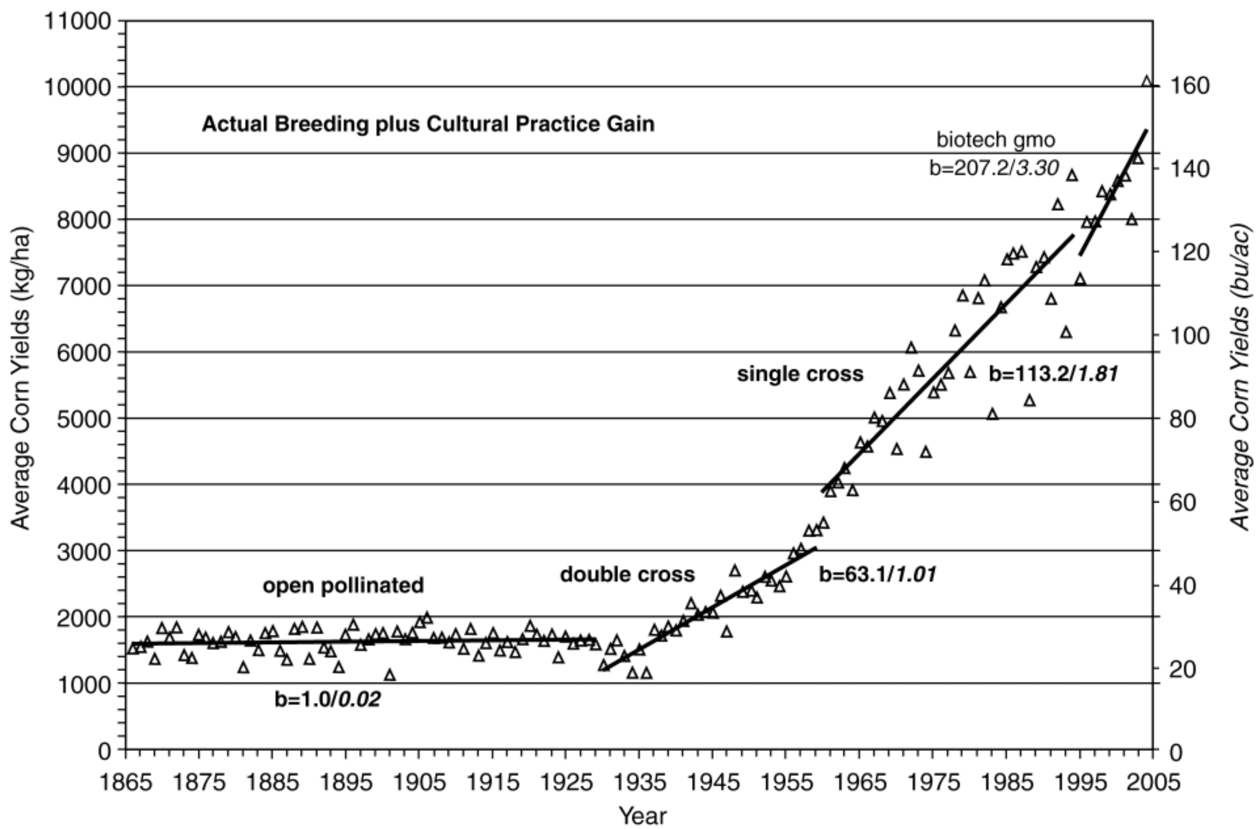


Fig. 11 Average U.S. corn yields and kinds of corn, CivilWar to 2004. ''b'' values (regressions kg bu21) indicate production gain per unit area per year (USDA-NASS, 2005). Based on Figure 11: Corn Grain Yields (University of Nebraska-Lincoln, 2004 http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1075412493&topicorder=10&maxto=12 From (Troyer, AF, 2006)

From (Troyer, AF, 2006)

"In 2001, corn became the highest tonnage crop worldwide:
557.6 million Mg of maize, 542.4 million Mg of rice (Oryza sativa L.) paddy, and 535.6 million Mg of wheat (Triticum aestivum L.) (UN/FAO, 2002). United States corn production was 53 million Mg [2 billion (2 3 1029) bushels] annually in the 1930s, when corn hybrids were first commercially grown, and yield averaged 1518 kg ha21 (24.2 bushels acre21). Corn production grew to 76 million Mg (3 billion bushels) annually in the 1950s, to 150 million Mg (6 billion bushels) annually in the 1970s, and to more than 229 million Mg (9 billion bushels) annually for the past 9 yr. The USDA-NASS (2005) estimates 2004 U.S. corn production at a record 299.7 million Mg (11.8 billion bushels) and the average yield is estimated at a record 10 059 kg ha21 (160.4 bushels acre21) (Fig. 1). At $150 per bag for 30 million bags, the annual U.S. seed-corn cost is $4.5 billion. At $2.50 per 25.4 kg (1 bushel) and 299.7 million Mg (11.8 billion bushels), the annual U.S. farm value is $29.5 billion. The relatively high cost of seed corn (|15% of the crop's farm value) is justified by higher yielding, newer hybrids.

I relate pertinent happenings in the phenomenal increases in U.S. corn yield and production. The increases over time are associated with better adaptedness, corn breeding, hybrid corn, mechanical harvest, better soil fertility (particularly more N), single-cross hybrids that are easily identified by the farmer (better hybrid choice), field-shelling harvest (faster feed back for yield), improved cultural practices (particularly higher plant densities), and biotechnology. Heterosis in hybrid corn is well used but poorly understood. I revisit the accepted origin of Corn Belt corn and its heterotic groups and patterns. I address adaptedness due to natural and human selection that caused race and cultivar formation; evolution of heterosis, genetic diversity, and heterotic gene action; corn hybrids including combining ability, heterotic groups and patterns; and mules as the hybrid corn prototype." (Troyer, AF, 2006)

Anonymous and Pland-Soil-Sciences-Library (2011), Corn Breeding: Lessons From the Past, Corn Grain Yields, 1930 to Today, Plant Breeding,, publ:
http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1075412493&topicorder=10&maxto=12 AND
http://www.ask-force.org/web/Yield/Corn-Breeding-Lessons-Plant-Soil-Library-2011.pdf

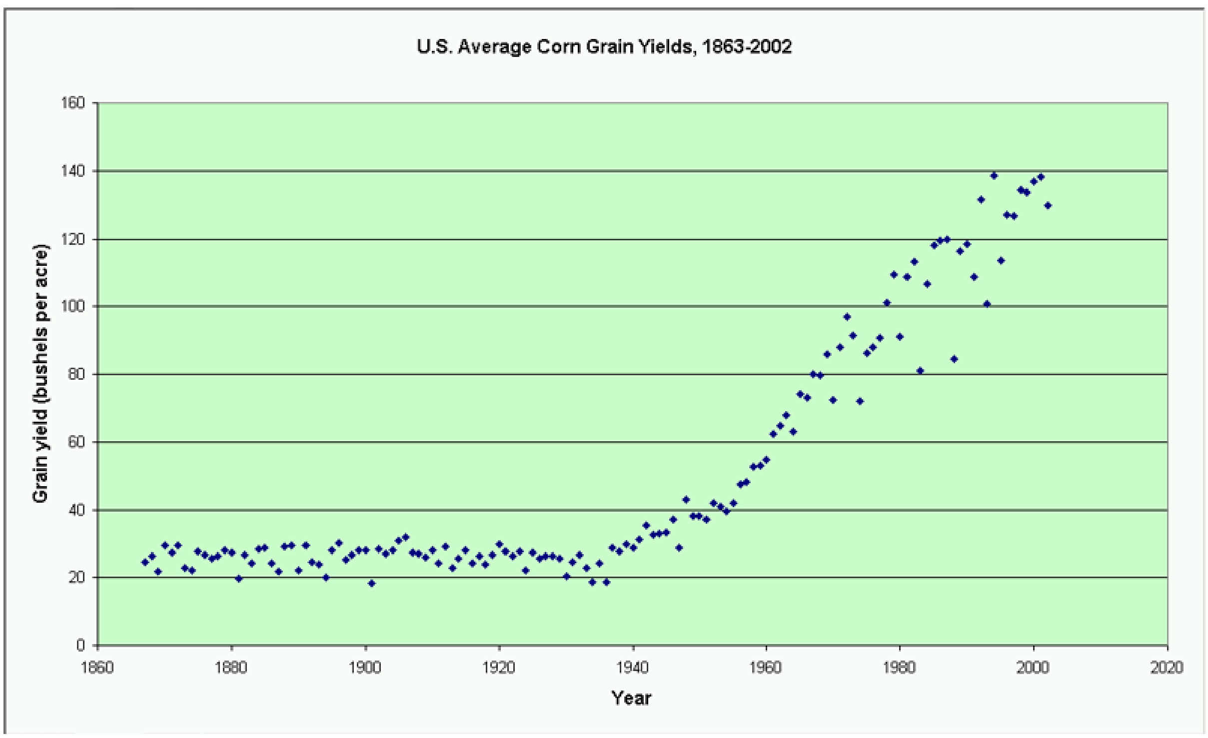
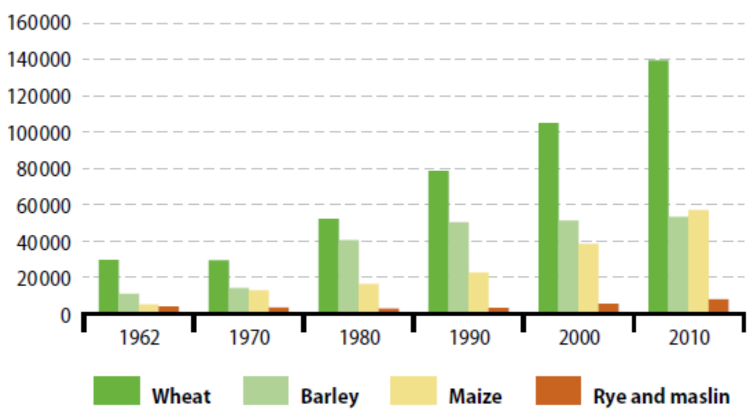


Fig. 12 The national average corn grain yield in the United States began to increase steadily in the 1940s (Figure 11). In the most recent decade, the average yield was 125 bushels per acre, nearly five times greater than 70 years before. Several studies conducted by universities have indicated that much of this improved yield was the result of improved genetics; that is, it occurred because farmers were planting improved varieties of corn developed through plant breeding. Greater use of fertilizer, more and better herbicides, improved soil tillage, and other altered production practices also contributed to the increased yields. Fig. 11 from (Anonymous & Pland-Soil-Sciences-Library, 2011)

Eurostat and C. C. e. al. (2012), Agriculture, fishery and forestry statistics Main results – 2010-11 Pocketbooks, 2010-2011, pp. 228, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-FK-12-001/EN/KS-FK-12-001-EN.PDF AND http://www.ask-force.org/web/Yield/Eurostat-Agriculture-fishery-forestry-statistics-2011.PDF

Figure 2: EC / EU ([1]) harvested production of main cereals, 1962-2010
(1 000 tonnes)



([1]) EC/EU: aggregate calculated for the countries being Member States in the reference year.

Source: Eurostat (online data code: apro_cpp_crop);

Fig. 13 EC/EU aggregate calculated for the countries being member States in the reference year, from (Eurostat & al., CCe, 2012).

Perry Mark J. (20111107), U.S. Corn Yields Have Increased Six Times Since the 1930s and Are Estimated to Double By 2030, pp. 6, http://mjperry.blogspot.ch/2011/11/corn-yields-have-increased-six-times.html#sthash.ohPWYwlt.dpuf AND http://www.ask-force.org/web/Yield/Perry-Carpe-Diem-US-Corn-Yields-1930-2030-20111107.pdf

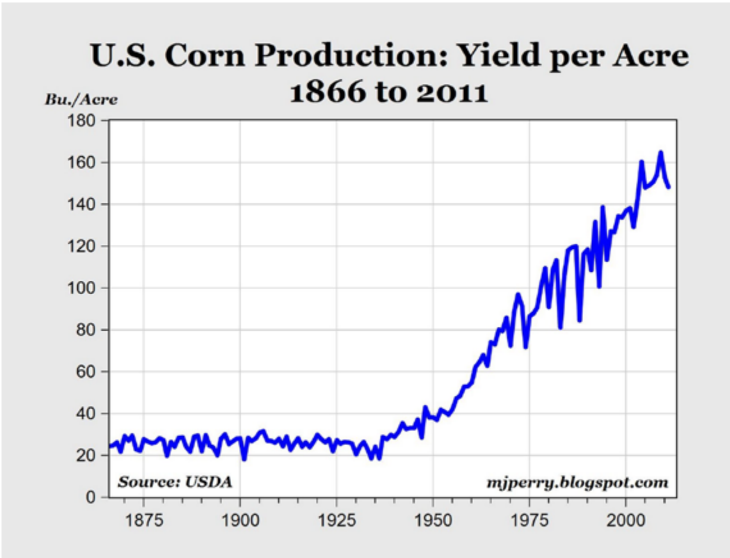


Fig. 14 US-corn production, yield per acre 1866 to 2011, Carpe Diem Prof. Marc J. Perry, University of Washington, From (Perry Mark J., 20111107).

Hofstrand Don (201111), Can the World Feed Nine Billion People by 2050? AgMRC Renewable Energy & Climate Change Newsletter, November 2011, pp. 11, http://www.agmrc.org/renewable_energy/renewable_energy/can-the-world-feed-nine-billion-people-by-2050/# AND http://www.ask-force.org/web/Yield/Hofstrand-Can-World-Feed-2050-201111.pdf

*"**Can Agriculture Meet Future Food Needs?***
World agriculture has met the food needs of an increased population and expanded world economy during the last half of the 20th Century, agriculture's ability to meet the needs of an additional two billion people during the first half of the 21st Century is an open question. The Food and Agriculture Organization estimates that food production will need to increase by 70 percent by 2050. Below I will discuss ways of increasing agricultural production and some of the issues involved in these methods. Increase Yields and/or Expand Cropland Area.
The traditional approach to increasing world food production has been by expanding production area and increasing yields. The historic increase in world production of the three major commodities of wheat, corn and soybeans is show in Figure 6. Production increased from just over 400 million metric tons in 1960 to over 1,700 million metric tons in 2010. Almost all of the increase came as a result of yield increases. Cropland area expanded only modestly over the time period."(Hofstrand Don, 201111).

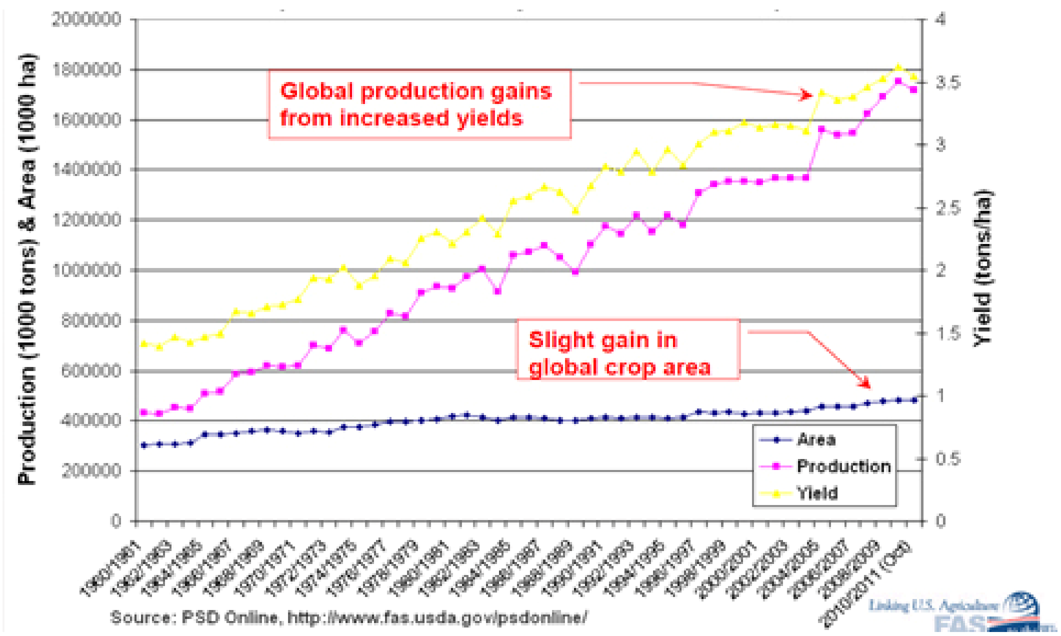


Fig. 15 2010 Global Production, Area & Yield (for Wheat, Soybeans and Corn) ***Increase Yields and/or Expand Cropland Area.*** **The traditional approach to increasing world food production has been by expanding production area and increasing yields. The historic increase in world production of the three major commodities of wheat, corn and soybeans is show in Figure 6. Production increased from just over 400 million metric tons in 1960 to over 1,700 million metric tons in 2010. Almost all of the increase came as a result of yield increases. Cropland area expanded only modestly over the time period. Fig. 6 from (Hofstrand Don, 201111), Source USDA**

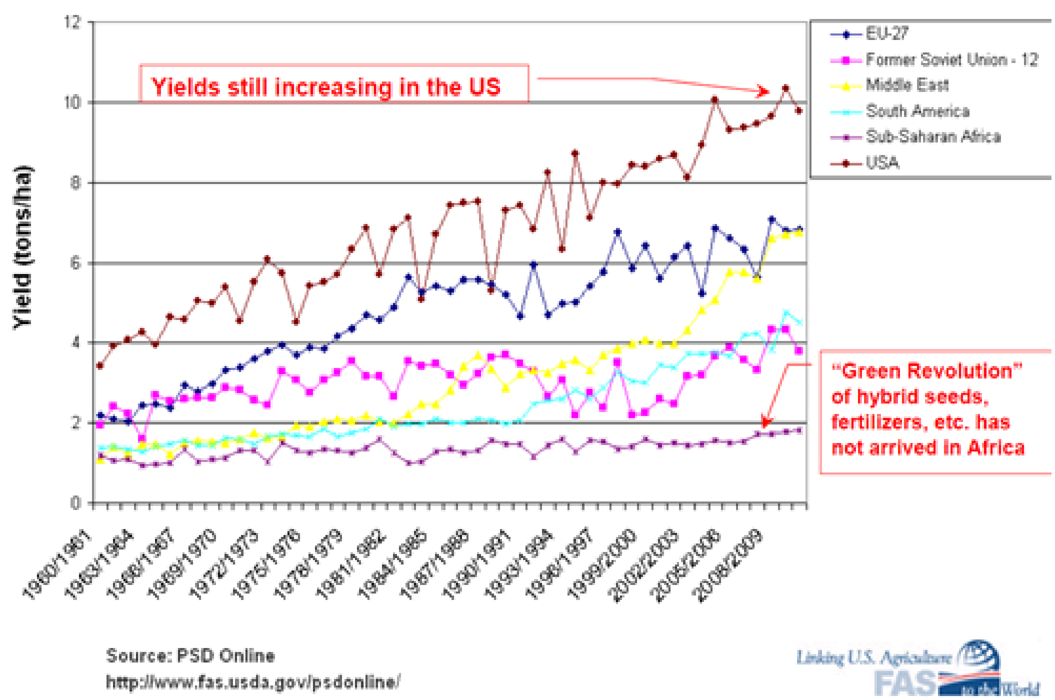


Fig. 16 Historic Corn Yields, USA yields at top, Europe in medium position, clear lagging of Subsaharan Africa, Green Revolution from India not arrived in Africa yet. From (Hofstrand Don, 201111) see Fig. 7

Inside Track (2013), GM Wheat, Wheat and maize relationship and GM implications for cereals, in: Inside Track, Magazine for the Arable Sector, July 2013, Inside Track, Cottenham, Cambridge, http://www.insidetrack.org.uk/?main_section=58 AND http://www.ask-force.org/web/Economics/Inside-Track-Maize-Yields-Comparison-2011.pdf

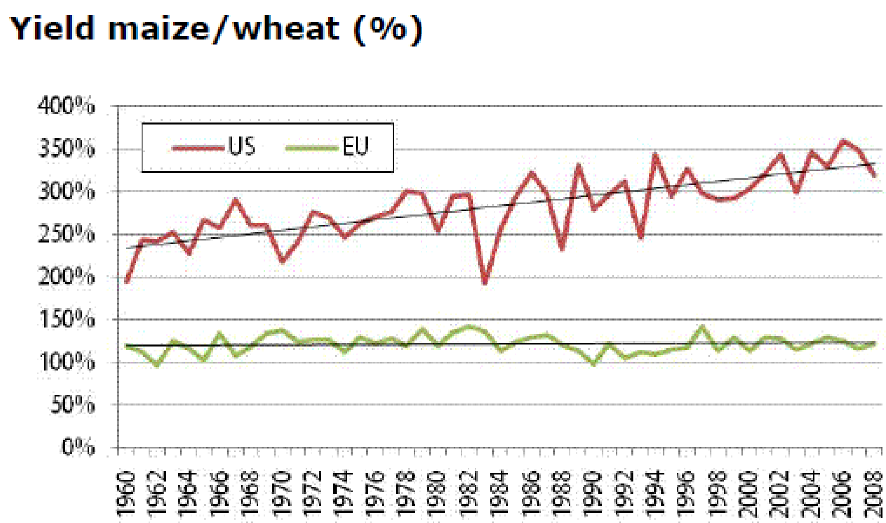


Fig. 17 For the foreseeable future, maize is likely to yield more than wheat. Maize is a semi-tropical plant, and under warm conditions and drought, is more efficient at capturing sunlight than wheat. (Maize has a C4 photosynthetic pathway rather than C3 as used by wheat). The obvious driver for change in area is change in relative yield. US maize yield has increased relative to wheat, while the European yield has remained static. While this might be expected to explain the difference, the relative price change over the last 10 years counteracts the yield gain (although recently it has been erratic). Prior to 1999, the price difference was more volatile with no obvious trend, although wheat still traded at a premium. Source USDA- analyzed InsideTrack, From (Inside Track, 2013)

12. Report of the National Research Committee 2010

In a summary, the report reflects the broad range of experts invited to compile an opinion on the topic of Impact of Genetically Engineered Crops on Farm Sustainability in the United States (National Research Council, 2010).

"With the advent of genetic-engineering technology in agriculture, the science of crop improvement has evolved into a new realm. Advances in molecular and cellular biology now allow scientists to introduce desirable traits from other species into crop plants. The ability to transfer genes between species is a leap beyond crop improvement through previous plantbreeding techniques, whereby desired traits could be transferred only between related types of plants. The most commonly introduced genetically engineered (GE) traits allow plants either to produce their own insecticide, so that the yield lost to insect feeding is reduced, or to resist herbicides, so that herbicides can be used to kill a broad spectrum of weeds without harming crops. Those traits have been incorporated into most varieties of soybean, corn, and cotton grown in the United States.

Since their introduction in 1996, the use of (GE crops in the United States has grown rapidly and accounted for over 80 percent of soybean, corn, and cotton acreage in the United States in 2009. Several National Research Council reports have addressed the effects of GE crops on the environment and on human health.1 However, the effects of agricultural biotechnology at the farm level-that is, from the point of view of the farmer-have received much less attention. To fill that information gap, the National Research Council initiated a study, supported by its own funds, of how GE crops have affected U.S. farmers-their incomes, agronomic practices, production decisions, environmental resources, and personal well-being. This report of the study's findings expands the perspectives from which genetic-

engineering technology has been examined previously. It provides the first comprehensive assessment of the effects of GE-crop adoption on farm sustainability in the United States (Box S-1)."

A few figures show clearly the benefits and positive developments of GM crops in the United States and elsewhere:

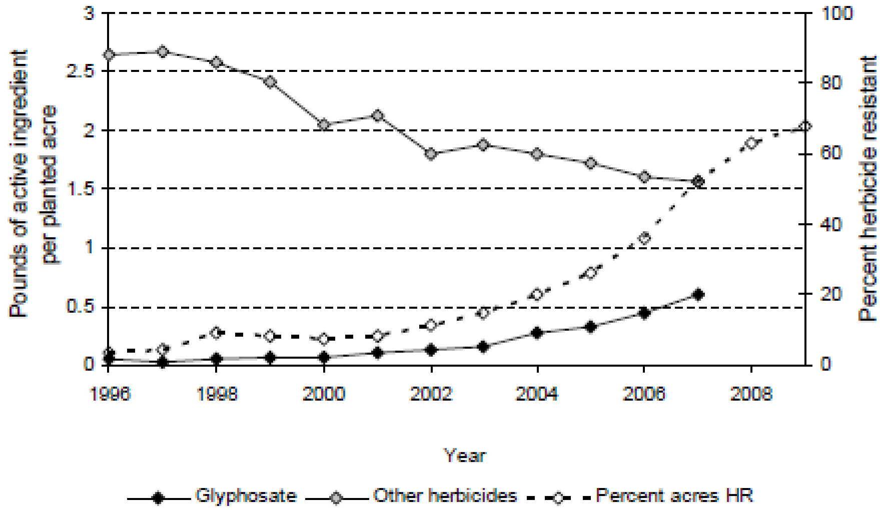


Fig. 18 Application of herbicide to corn and percentage of HR corn. NOTE: The strong correlation between the rising percentage of herbicide-resistant (HR) corn acres planted over time, the increased applications of glyphosate, and the decreased use of other herbicides suggests but does not confirm causation between these variables. SOURCES: USDA-NASS, 2001; 2003, 2005, 2007, 2009a, b; citations see report, and (Fernandez-Cornejo, J & Caswell, MF, 2006).

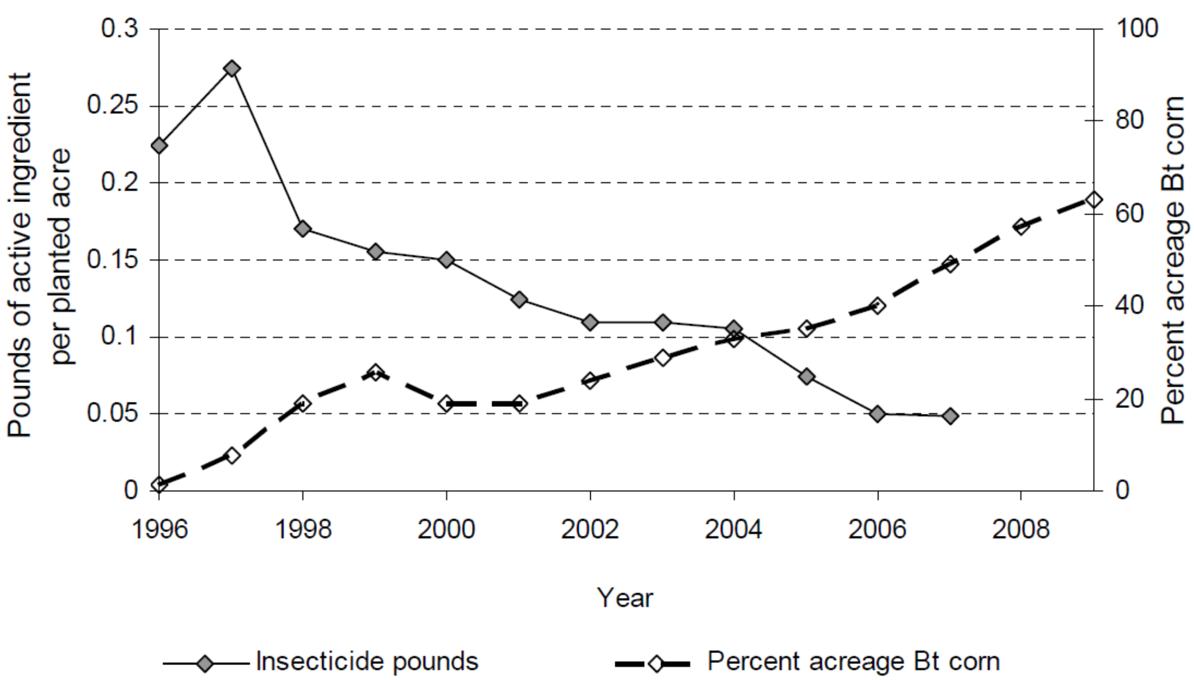


Fig. 19 Pounds of insecticide applied per planted acre and percent acres of Bt corn, respectively. NOTE: The strong correlation between the rising percentage of Bt corn acres planted over time and the decrease in insecticide pounds per planted acre suggests but does not confirm

causation between these variables. SOURCES: USDA-NASS, 2001; 2003, 2005, 2007, 2009a, b; (see report) and (Fernandez-Cornejo, J & Caswell, MF, 2006).

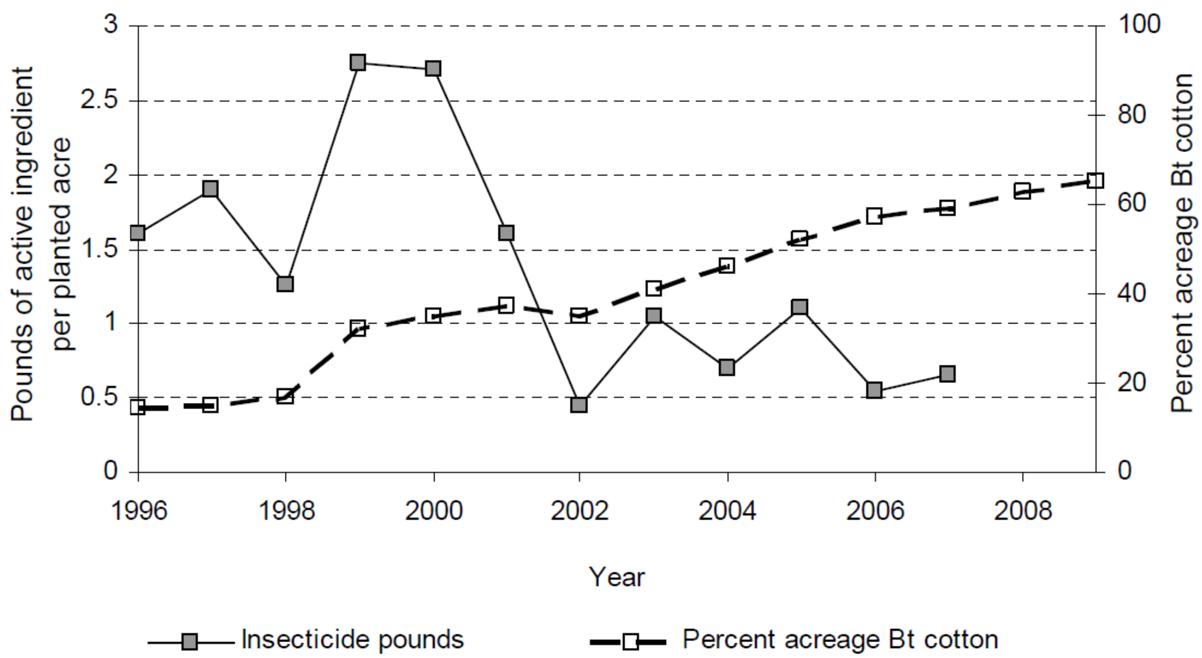


Fig. 20 Pounds of insecticide applied per planted acre and percent acres of Bt cotton, respectively. NOTE: The strong correlation between the rising percentage of Bt cotton acres planted over time and the decrease in insecticide pounds per planted acre suggests but does not confirm causation between these variables. SOURCES: USDA-NASS, 2001; 2003, 2005, 2007, 2009a, b; (see report) and (Fernandez-Cornejo, J & Caswell, MF, 2006).

The conclusion No. 4 of the report:

*"**Conclusion 4**. Commercialized GE traits are targeted at pest control, and when used properly, they have been effective at reducing pest problems with economic and environmental benefits to farmers. However, genetic engineering could be used in more crops, in novel ways beyond herbicide and insecticide resistance, and for a greater diversity of purposes. With proper management, genetic-engineering technology could help address food insecurity by reducing yield losses through its introduction into other crops and with the development of other yield protection traits like drought tolerance. Crop biotechnology could also address "public goods" issues that will be undersupplied by the market acting alone. Some firms are working on GE traits that address public goods issues. However, industry has insufficient incentive to invest enough in research and development for those purposes when firms cannot collect revenue from innovations that generate net benefits beyond the farm. Therefore, the development of these traits will require greater collaboration between the public and private sectors because the benefits extend beyond farmers to the society in general. The implementation of a targeted and tailored regulatory approach to GE-trait development and commercialization that meets human and environmental safety standards while minimizing unnecessary expenses will aid this agenda (Ervin, D & Welsh, R, 2006).*

The report is commented by an independent author from a Californian University: the full text can also serve as an excellent comment for the piece on yield and performance of GM crops:

Ronald Pamela and McWilliams James E. (20100514), Genetically Engineered Distortions, New York Times, 14. May 2010, pp. 1, http://www.nytimes.com/2010/05/15/opinion/15ronald.html[5/19/2010 AND http://www.ask-force.org/web/Yield/Ronald-GM-Distortions-NY-Times-201005.PDF

A REPORT by the National Research Council last month gave ammunition to both sides in the debate over the cultivation of genetically engineered crops. More than 80 percent of the corn, soybeans and cotton grown in the United States is genetically engineered, and the

report details the "long and impressive list of benefits" that has come from these crops, including improved soil quality, reduced erosion and reduced insecticide use.
It also confirmed predictions that widespread cultivation of these crops would lead to the emergence of weeds resistant to a commonly used herbicide, glyphosate (marketed by Monsanto as Roundup). Predictably, both sides have done what they do best when it comes to genetically engineered crops: they've argued over the findings.

Lost in the din is the potential role this technology could play in the poorest regions of the world — areas that will bear the brunt of climate change and the difficult growing conditions it will bring. Indeed, buried deep in the council's report is an appeal to apply genetic engineering to a greater number of crops, and for a greater diversity of purposes.

Appreciating this potential means recognizing that genetic engineering can be used not just to modify major commodity crops in the West, but also to improve a much wider range of crops that can be grown in difficult conditions throughout the world.

Doing that also requires opponents to realize that by demonizing the technology, they've hindered applications of genetic engineering that could save lives and protect the environment.

Scientists at nonprofit institutions have been working for more than two decades to genetically engineer seeds that could benefit farmers struggling with ever-pervasive dry spells and old and novel pests. Drought-tolerant cassava, insect-resistant cowpeas, fungus-resistant bananas, virus-resistant sweet potatoes and high-yielding pearl millet are just a few examples of genetically engineered foods that could improve the lives of the poor around the globe.

For example, researchers in the public domain have been working to engineer sorghum crops that are resistant to both drought and an aggressively parasitic African weed, Striga.

In a 1994 pilot project by the United States Agency for International Development, an experimental variety of engineered sorghum had a yield four times that of local varieties under adverse conditions. Sorghum, a native of the continent, is a staple throughout Africa, and improved sorghum seeds would be widely beneficial.

As well as enhancing yields, engineered seeds can make crops more nutritious. A new variety of rice modified to produce high amounts of provitamin A, named Golden Rice, will soon be available in the Philippines and, if marketed, would almost assuredly save the lives of thousands of children suffering from vitamin A deficiency.

There's also a sorghum breed that's been genetically engineered to produce micronutrients like zinc, and a potato designed to contain greater amounts of protein.

To appreciate the value of genetic engineering, one need only examine the story of papaya. In the early 1990s, Hawaii's papaya industry was facing disaster because of the deadly papaya ringspot virus. Its single-handed savior was a breed engineered to be resistant to the virus. Without it, the state's papaya industry would have collapsed. Today, 80 percent of Hawaiian papaya is genetically engineered, and there is still no conventional or organic method to control ringspot virus.

The real significance of the papaya recovery is not that genetic engineering was the most appropriate technology delivered at the right time, but rather that the resistant papaya was introduced before the backlash against engineered crops intensified.

Opponents of genetically engineered crops have spent much of the last decade stoking consumer distrust of this precise and safe technology, even though, as the research council's previous reports noted, engineered crops have harmed neither human health nor the environment.

In doing so, they have pushed up regulatory costs to the point where the technology is beyond the economic reach of small companies or foundations that might otherwise develop a wider range of healthier crops for the neediest farmers. European restrictions, for instance, make it virtually impossible for scientists at small laboratories there to carry out field tests of engineered seeds.

As it now stands, opposition to genetic engineering has driven the technology further into the hands of a few seed companies that can afford it, further encouraging their monopolistic tendencies while leaving it out of reach for those that want to use it for crops with low (or no) profit margins.

The stakes are too high for us not to make the best use of genetic engineering. If we fail to invest responsibly in agricultural research, if we continue to allow propaganda to trump science, then the potential for global agriculture to be productive, diverse and sustainable will go unfulfilled. And it's not those of us here in the developed world who will suffer the direct consequences, but rather the poorest and most vulnerable.

Pamela C. Ronald, a professor of plant pathology at the University of California, Davis, is the co-author of "Tomorrow's Table: Organic Farming, Genetics and the Future of Food." James E. McWilliams, a history professor at Texas State University at San Marcos, is the author of "Just Food." (Ronald Pamela & McWilliams James E., 20100514)

13. Future developments in crop yields

Tester, M. and P. Langridge (2010), Breeding Technologies to Increase Crop Production in a Changing World Science, 327, 5967, pp. 818-822, http://www.sciencemag.org/content/327/5967/818.abstract AND http://www.ask-force.org/web/Yield/Tester-Breeding-Technologies-Increase-2010.pdf

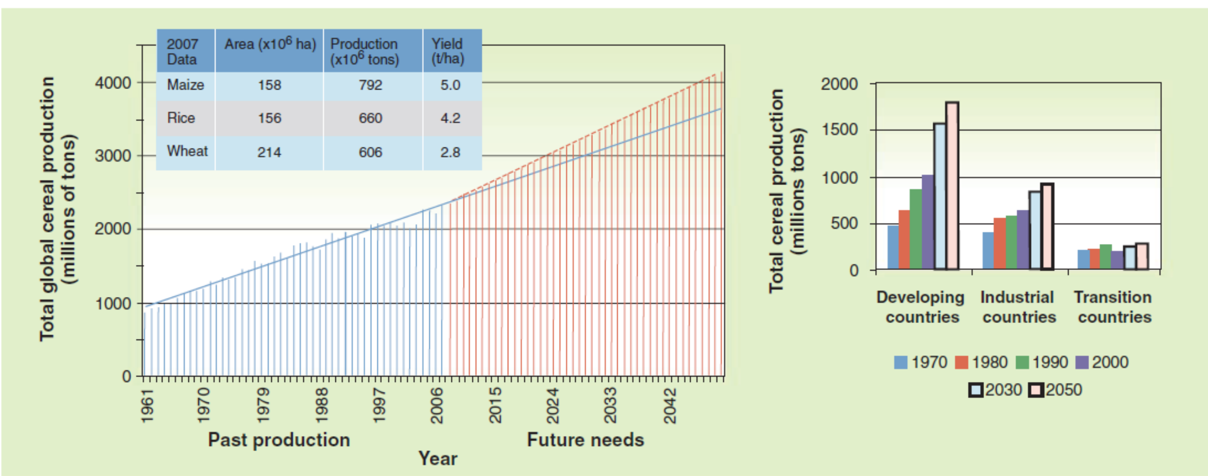


Fig. 21 Cereal production targets. (Left) Global cereal production has risen from 877 million metric tons in 1961 to 2351 million metric tons in 2007 (blue). However, to meet predicted demands (3), production will need to rise to over 4000 million metric tons by 2050 (red). The rate of yield increase must move from the blue trend line (32 million metric tons per year) to the red dotted line (44 million metric tons per year) to meet this demand, an increase of 37%. The inset table shows the 2007 data for the three major cereals. Data are from the FAO: http://faostat.fao.org/. (Right) The greatest demand for yield increases will be from countries in the developing world. [Based on FAO data (26)].

14. Links to a collection of useful slides related to yield and development of crops

In order to help convey this message, here below a collection of slides, partially shown in the above.
http://www.botanischergarten.ch/Yield/Yield-Related-1.ppt
http://www.botanischergarten.ch/Yield/Yield-Related-1.pdf

Two selected slides show the contrast between progressive United States agriculture with a decisive hike in yield of corn (a bit less for soybean), and the not so positive situation in Europe, the result of farmers and resisting persistently to new agricultural technologies:

http://www.botanischergarten.ch/Yield/Yield-Comparison-Corn-USA-Europe.pdf
http://www.botanischergarten.ch/Yield/Yield-Comparison-Corn-USA-Europe.ppt

From (Carpenter, JE, 2010)
http://www.botanischergarten.ch/Benefits/Carpenter-Peer-Reviewed-Surveys-2010.ppt

15. The debate on organic versus conventional agriculture yield

15.1. Introduction, early papers

As we have seen in section 11, it is really important what data units and elements you are comparing. If you compare low input conventional agriculture with well-developed high input organic farming, you might even see similar yield results or even higher yields for organic farming. Data manipulation has been even more blatant with the famous study of (Badgley, C, et al., 2007), a study which committed some major mistakes such as adding yearly results instead of calculation mean values, see comments in (Avery, A, 2007):

"3. Double, triple, even quintuple counting of organic yields from the same few research projects;" (Avery, A, 2007)

However, organic farming and biotech-based farming could well go together, as the author has shown in earlier years (Ammann, K, 2006, Ammann, K, 2007a, Ammann, K, 2007b, Ammann, K, 2007c, Ammann, K, 2007d, Ammann K. in:, et al., 2004) and with more details in (Ammann, K, 2008, Ammann, K, 2009, Ammann, K & van Montagu, M, 2009) and the 'organotransgenic' view gets more and more support: (Ronald, PC & Adamchak, RW, 2008), (deRenobales-Scheifler, M, 2009) and (Ryffel, GU, 2011, Ryffel, GU, 2012), and most recently: (EASAC, 20130627, Heap Brian, 20130626)

The ending paragraph of (Ammann, K & van Montagu, M, 2009) may be enough here to describe the issues:

In a publication in this journal (New Biotechnology 25:101–107, 2009), the analysis of such new paradigms revealed that there are ample reasons, even in accordance with most of the official rules of organic farming, why certain transgenic crops could well fit into new agricultural practices. In the second part of the analysis in this issue, it can be demonstrated that some organic practices could very well be adopted by hi-tech agriculture; indeed, they actually fit well into modern concepts of highyield agriculture, especially when it comes to the adoption of biodiversity-friendly landscapes. Moreover, new insights in resistance management – by introducing a concept of crops with stacked genes or even better by introducing seed mixtures of modern traits, which could be assembled with the help of new knowledge in community ecology and adapted to local needs – might be a way forward. Finally, a future oriented and dynamic concept of sustainability is introduced, taking into account innovative agro-ecological, social and evolutionary management systems. (Ammann, K & van Montagu, M, 2009)

Klaus Ammann (Guest Professor), Sabanci University, Istanbul, Turkey

Marc van Montagu, European Federation of Biotechnology

15.2. A major paper comparing yield of organic and conventional agriculture, a long term study

A seminal paper has been published 2012, comparing yields in organic and conventional agriculture: (Seufert, V, et al., 2012). The summary:

"Numerous reports have emphasized the need for major changes in the global food system: agriculture must meet the twin challenge of feeding a growing population, with rising demand for meat and high-calorie diets, while simultaneously minimizing its global environmental impacts (Godfray, HCJ, et al., 2010) and (Foley, JA, et al., 2011). Organic farming—a system aimed at producing food with minimal harm to ecosystems, animals or humans—is often proposed as a solution n3,4. However, critics argue that organic agriculture may have lower yields and would therefore need more land to produce the same amount of food as conventional farms, resulting in more widespread deforestation and biodiversity loss, and thus undermining the environmental benefits of organic practices5. Here we use a comprehensive meta-analysis to examine the relative yield performance of organic and conventional farming systems globally. Our analysis of available data shows that, overall, organic yields are typically lower than conventional yields. But these yield differences are highly contextual, depending on system and site characteristics, and range from 5% lower organic yields (rain-fed legumes and perennials on weak acidic to weak-alkaline soils), 13% lower yields (when best organic practices are used), to 34% lower yields (when the conventional and organic systems are most comparable). Under certain conditions—that is, with good management practices, particular crop types and growing conditions—organic systems can thus nearly match conventional yields, whereas under others it at present cannot. To establish organic agriculture as an important tool in sustainable food production, the factors limiting organic yields need to be more fully understood, alongside assessments of the many social, environmental and economic benefits of organic farming systems."(Seufert, V, et al., 2012)

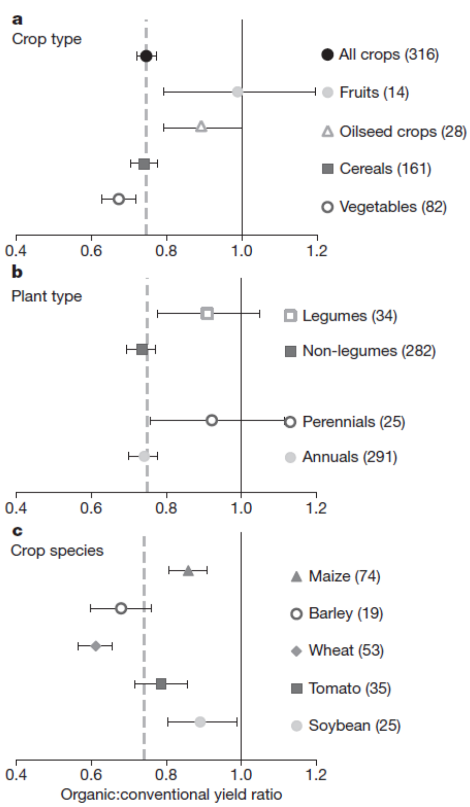


Fig. 22 Influence of N input, soil pH, best management practices, time since conversion to organic management, irrigation and country development. a–f, Influence of theamount ofNinput (a), soilpH(b), the use of best management practices (BMP; c), time since conversion to

organic management (d), irrigation (e) and country development (f) on organic-toconventional yield ratios. For details on the definition of categorical variables see Supplementary Tables 1–3. Values are mean effect sizes with 95% confidence intervals. The number of observations in each class is shown in parentheses. The dotted line indicates the cumulative effect size across all classes. (Seufert, V, et al., 2012)

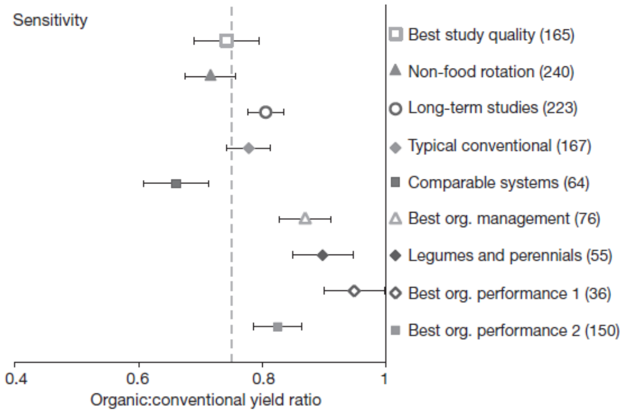


Fig. 23 Sensitivity study of organic-to-conventional yield ratios. Best study quality, peer-reviewed studies using appropriate study design and making appropriate inferences; non-food rotation, studies where both systems have a similar duration of non-food crops; long-term studies, excludes very short duration and recently converted studies; typical conventional, restricted to commercial conventional systems with yields comparable to local averages; comparable systems, studies that use appropriate study design and make appropriate inferences, where both systems have the same non-food rotation length and similar N inputs; best org. management, excludes studies without best management practices or crop rotations; legumes and perennials, restricted to leguminous and perennial crops; best org. performance 1, rain-fed legumes and perennials on weak-acidic to weak-alkaline soils; best org. performance 2, rain-fed and weak-acidic to weak-alkaline soils. Values are mean effect sizes with 95% confidence intervals. The number of observations is shown in parentheses. The dotted line indicates the effect size across all studies.

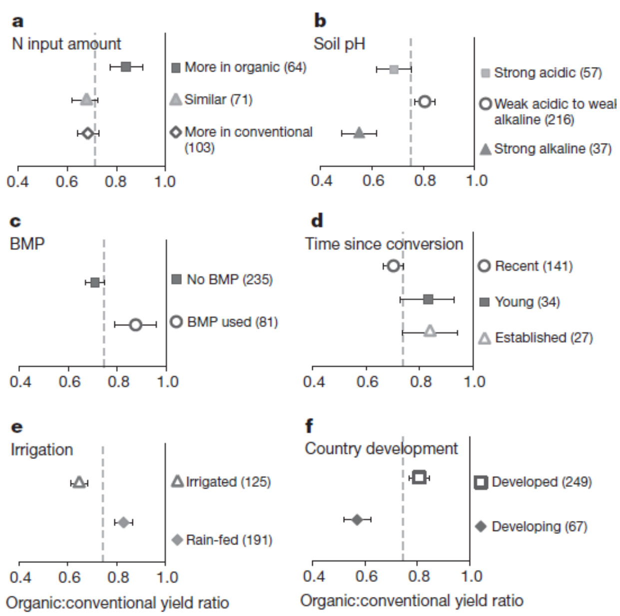


Fig. 24 Influence of N input, soil pH, best management practices, time since conversion to organic management, irrigation and country development. a–f, Influence of the amount of N input (a), soil pH(b), the use of best management practices (BMP; c), time since conversion to organic management (d), irrigation (e) and country development (f) on organic-to conventional yield ratios. For details on the definition of categorical variables see Supplementary Tables 1–3. Values are mean effect sizes with 95% confidence intervals. The number of observations in each class is shown in parentheses. The dotted line indicates the cumulative effect size across all classes.

Some summarizing remarks from (Seufert, V, et al., 2012) which the author can fully support:

"The results of our meta-analysis differ dramatically from previous results (Badgley, C, et al., 2007). ***Although our organic performance estimate is lower than previously reported in developed countries (- 20% compared to - 8%), our results are markedly different in developing countries (- 43% compared to + 80%).*** *This is because the previous analysis mainly included yield comparisons from conventional low-input subsistence systems, whereas our data set mainly includes data from high input systems for developing countries. However, the previous study compared subsistence systems to yields that were not truly organic, and/or from surveys of projects that lacked an adequate control. Not a single study comparing organic to subsistence systems met our selection criteria and could be included in the meta-analysis. We cannot, therefore, rule out the claim[16] that organic agriculture can increase yields in smallholder agriculture in developing countries. But owing to a lack of quantitative studies with appropriate controls we do not have sufficient scientific evidence to support it either. Fortunately, the Swiss Research Institute of Organic Agriculture (FiBL) recently established the first long-term comparison of organic and different conventional systems in the tropics (Muriuki, A, et al., 2012). Such well-designed long-term field trials are urgently needed." (Seufert, V, et al., 2012)*

From the cited conference summary of (Muriuki, A, et al., 2012) - shows first results of a 3-years comparison under more precise premises:

"The trial features 4 treatments (Conventional High, Conventional Low, Organic High and Organic Low) in a Randomised Complete Block Design (RCBD). Nutrients in 'Conventional' treatments are supplied by farmyard manure, diammonium phosphate, calcium ammonium nitrate and compost, while Tithonia diversifolia, and rock phosphate supply nutrients in 'Organic' treatments. Pests are controlled using biopesticides and chemical products in 'Organic' and 'Conventional' treatments, respectively. A three-year, maize/baby corn based rotation system is followed. There were no treatment differences in yield (p=0.101) in 2007, but stover weights in Conventional High were superior to Organic Low and indistinguishable from Conventional Low and Organic High (p = 0.034). Differences between treatments however were observed in 2011 yields (p = 0.027) and stover (p = 0.003). Dry matter yields in Conventional High and Organic High treatments were lower than in Organic Low and indistinguishable from Conventional Low. Whereas stover weights at the same input level were indistinguishable, they were higher at the higher input level. The results suggested that organic farming may be a viable option for tropical Africa." (Muriuki, A, et al., 2012).

15.3. Agro-Ecology, a buzz word found worldwide for the promotion of an agriculture with more yield and less environmental impact, a skeptics view, excerpt of chapter 4.2 of Ammann K. 20120620

Ammann Klaus (20120620)
Chapter 27: Advancing the cause in emerging economies Successful Agricultural Innovation in Emerging Economies, Bennett David and Jennings Richard, Cambridge, Cambridge University Press, 27
http://www.ask-force.org/web/CUP-Success-GM-crops/Ammann-Advancing-Cause-Emerging-20120802.pdf

The Controversy about Agro-Ecology

The eco-imperialist attitude towards farmers in the developing world should be seen critically by (Paarlberg, R, 2000, Paarlberg, R, 2006, Paarlberg, R, 2008, Paarlberg, R, 2009a, Paarlberg, R, 2009b, Paarlberg, R, 2010). He, and many other authors cast doubts on the frequent claims (and this is supported by this author), that agro-ecology-based production strategies would be better for smallholder farmers than solutions including modern breeding, a claim which is not supported by data: The fact is, that some 80% of farmers from the developing world who have adopted GM crops are smallholder farmers making considerable economic profits with the technology (Brookes, G & Barfoot, P, 2007) and (Qaim, M, et al., 2007a, Qaim, M & Stein, AJ, 2009a, Qaim, M & Stein, AJ, 2009b)).

The numerous papers by Miguel Altieri (a selection: (Altieri, MA & Letourneau, DK, 1982, Altieri, MA, et al., 1983, Altieri, MA, 1989, Altieri, MA, 1999, Altieri, MA & Rosset, P, 1999, Altieri, MA, 2000b, Altieri, MA, 2002, Altieri, MA & Nicholls, CI, 2003, Altieri, MA & Toledo, VM, 2011) offer tempting concepts on agro-ecology with some good elements and ideas, but they are not based on hard production data. Except for one publication (Altieri, MA, 2000a) with focus on production but lacking sufficient details to allow verification, his concepts are more wishful thinking than agricultural reality. Other notorious and often cited examples of seemingly positive yield results by applying agro-ecological methods (even a doubling of yield is claimed) come from Jules Pretty: (Pretty, J, et al., 2011, Pretty, JN, et al., 2005). They are efficiently debunked by (Phalan, B, et al., 2006).

a) There is a strong selection bias towards successful projects.
b) Methods used to measure changes in yields, water and pesticide use, and carbon sequestration are poorly explained, and therefore, hard to reproduce
c) Crucially, the study lacks adequate controls, thereby failing to show that it is the introduction of resource-conserving practices which is responsible for reported increases in yield and sustainability.
d) The extent to which these practices provide greater net benefits to farmers than conventional techniques is unclear.

In the answers to the critique of Phalan, Pretty et al. (Pretty, J, et al., 2006) basically admit the weakness of their study, but offer the excuse of unreasonably high costs to overcome the flaws in field data gathering. Nevertheless, Miguel Altieri seems to be 100% convinced that his way is the right one, otherwise it would be hard to understand why he helps fundamentalists to occupy research areas near Berkeley, hindering ag-biotech research with the false accusation, that it is supported by corporate money and he also supports the demonizing of biotech maize: (Brooks Jon, 20120511).

Another sometimes cited paper from Africa, describing a comparative field research with maize cultivation, shows the seemingly positive effects of the push-pull technology,developed jointly by the International Center of Insect Physiology and Ecology (ICIPEG, Nairobi) and Rothamstead Research (UK) - basically a fascinating idea to attract and trap pest insects with the weed Desmodium, but a careful study of the paper shows bias: (Hassanali, A, et al., 2008). It compares a traditional inefficient maize with their own push and pull technology, getting thus a favorable result. If the team would have worked with a modern Bt maize, the result would most probably have been reversed.

More recent papers show better results as Khan Z.R. can demonstrate in (Khan, Z, et al., 2011):

Both companion plants provide high value animal fodder, facilitating milk production and diversifying farmers' income sources. The technology is appropriate to smallholder mixed cropping systems in Africa. ***It effectively addresses major production constraints, increases maize yields from below 1 to 3.5t/ha,*** *and is economical as it is based on locally available plants, not expensive external inputs. Adopted by over 30,000 farmers to date in East Africa, key factors in its further up-scaling include effective technology dissemination, adaptability of companion plants for climate resilience, capacity building and multi-stakeholder collaboration, integration with livestock husbandry, improvement in input accessibility and creation of a supportive policy framework.*

More papers from the same research group: (Khan, ZR, et al., 2008a, Khan, ZR, et al., 2008b, Khan, ZR, et al., 2008c, Khan, ZR, et al., 2010)

Clearly: the hard reality today is that we urgently need to produce more - on the basis of enhancing yield dramatically, the gaps are clear, and astonishingly enough those gaps are higher in Eastern and Central Europe than in Africa: (Hengsdijk, H & Langeveld, JWA, 2009) see fig. 3.5 p.14.

15.4. Important reasons behind the divide between organic and biotech crops: The Genomic Misconception

This view, in the last few years with growing resonance, also calls for a reshuffling of the regulation from process orientation towards product orientation, an extensive account and scientific argumentation for the Canadian regulatory procedures, including the history of the transatlantic divide in regulation of GM crops, is in print: (Ammann Klaus, 20130415).

There are two major myths behind the resistance of organic farmers

a) Genetic engineering is hurting the "Genomic Integrity" of cultivated crops, as stated in several papers by E. Lammerts van Bueren and her research group in Wageningen: (Lammerts van Bueren, ET, et al., 2002, Van Bueren, ETL, et al., 2002, Van Bueren, ETL, et al., 2003, Van Bueren, ETL & Struik, PC, 2004, Van Bueren, ETL & Struik, PC, 2005, Van Bueren, ETL, et al., 2007a, van Bueren, ETL, et al., 2008, Verhoog, H, et al., 2003, Verhoog, H, et al., 2007)

b) Regulation should concentrate on processes instead of products (Van Bueren, ETL, et al., 2007b)

15.5. Critique of arguments, why organic farming rejects biotech crops

While the concept of organic farming contains good elements, it is often also distorted by ideological bias, foremost the one against modern breeding methods. Biodynamic agriculture, based on the ideas of Rudolf Steiner (Steiner, R, 1958), is an mix of interesting spiritual thought and traditional down to earth knowledge, again needing to be carefully scrutinized and to sort the wheat from the chaff. Here I concentrate on some of the mainstream arguments – why e.g. organic farmers nearly all reject modern plant breeding with transgenesis and many rules also reject mutational breeding and even distant hybridization.

Lammerts-Van Buhren et al. (Van Bueren, ETL, et al., 2003) try to explain on the molecular level, why organic farming cannot accept genetic engineering with a number of arguments. Following Verhoog (Verhoog, H, et al., 2003), they state that the *concept of naturalness* of organic agriculture not only leads to the avoidance of inorganic, chemical inputs and to the application of other agro-ecological principles, but also implies integrity of the crops as a whole. This concept also embraces their definition of the *intrinsic integrity of plant* genomes taking into account a *bio-centric perspective* (both terms lack a proper definition, more comments are given in (Ammann, K, 2007c).

From the above provided definition of the nature of plants and their qualities, a number of criteria, characteristics, and principles for organic plant breeding and propagation techniques are listed by the authors for exclusion: Besides transgenesis all breeding methods resulting in mutants through chemicals like colchicine or gamma radiation, all methods not allowing a full life cycle of the plant, and all methods manipulating the genome of the organisms etc. should be excluded.

Unfortunately, the authors completely miss the point that the structure and assembly of DNA has been changed heavily over the decades and centuries of traditional breeding. Modern wheat in all its variants and traits used today – also by organic farmers – is a product of processes, wherein the "intrinsic value of the genomic naturalness" has been completely ignored and any imaginable change has been successfully integrated. In an extensive study 58 major types of chromosomal rearrangements have been found (Badaeva, ED, et al., 2007) alone in wheat. As a matter of fact, most major crops have been subject to a multitude of genomic changes and chromosomal inversions, translocations etc. The reality is, whether we accept it for any kind of definition or not, that most of the principles on the molecular level advocated by (Van Bueren, ETL, et al., 2002, Van Bueren, ETL, et al., 2003, Van Bueren, ETL & Struik, PC, 2004, Van Bueren, ETL & Struik, PC, 2005, Verhoog, H, et al., 2003) are clearly violated by almost all existing modern crop traits and cannot be redone, unless one could theoretically return to the mostly vanished ancestral traits with all their dramatic disadvantages.

Genetic information is frequently disturbed by introduction of modified or mismatch bases into duplex DNA, and hence all organisms contain DNA repair systems to restore normal genetic information by removing such damaged bases or nucleotides and replacing them by correct ones. (Baarends, WM, et al., 2001, Morikawa, K & Shirakawa, M, 2001)

So, in reality, the principle of the 'intrinsic values of the plant genome' is a fiction and not based on the science. Also the working papers of FIBL, authored by Karutz, do not really help here, since they avoid going into modern molecular biology (Karutz, C, 1999a, Karutz, C, 1999b).

The whole concept of violation of the intrinsic naturalness of the genome by inserting alien genes from other species across the natural species barrier is also falsified by the occurrence of a naturally transgenic grass: see the case of a naturally transgenic grass discussed by (Ghatnekar, L, et al., 2006).

It is questionable to stress the overcoming of natural hybridization barriers by genetic engineering, since this has been done by traditional breeding methods in former decades. There is the example of 'somatic hybridization' (i.e. non-sexual fusion of two somatic cells). The advantage of this method is that by the fusion of cells with different numbers of chromosomes (for instance different species of Solanum) fertile products of the crossing can be obtained at once because diploid cells are being somatically fused. Polyploid plants are obtained containing all the chromosomes of both parents instead of the usual half set of chromosomes from each after meiosis. For this, cells are required whose cell walls have been enzymatically removed and are only enclosed by a membrane (protoplasts). With the loss of their cell walls, protoplasts have also lost their typical shape and are spherical like egg cells. This mixture of cells to be fused is then exposed to electric pulses. In order to get from the cell mixture the 'right' product of the fusion (since fusion of two cells from similar plants can also occur) one different selectable character in each of the original plants is necessary, parallel to the methods used in transgenesis. Only cells that survive this double selection are genuine products of fusion. Protoplast fusion was investigated and applied to potatoes and citrus fruits, e.g. (Miranda, M, et al., 1997, Nouri-Ellouz, O, et al., 2006, Przetakiewicz, J, et al., 2007) . In the EU, regulations cover the deliberate release of genetically modified organisms into the environment, but somatic hybrids are not considered as GMO's and do not require authorization. The most recent draft of the EU organic regulations in which the introduction of GMO's into organic cultivation is for-bidden, follows the above definition.

Moreover, the concept of violated intrinsic naturalness of the genomes by transgenity is falsified by the publications of Arber, (Nobel Laureate 1978), where he compared designed genetic alterations (including genetic engineering) with the spontaneous genetic variation known to form the substrate for biological evolution (Arber, W, 2002):

"Interestingly, naturally occurring molecular evolution, i.e. the spontaneous generation of genetic variants has been seen to follow exactly the same three strategies as those used in genetic engineering. These three strategies are:

(a) small local changes in the nucleotide sequences,
(b) internal reshuffling of genomic DNA segments, and
(c) acquisition of usually rather small segments of DNA from another type of organism by horizontal gene transfer."

See also (Arber, W, 2000, Arber, W, 2003, Arber, W, 2004) and also (Trewavas, A & Leaver, C, 2000) in writings which confirm this important comparison on the genomic level of evolutionary and modern plant breeding processes. But there are of course, despite all the similarities, some major differences: Natural mutation acts in a natural time scale, i.e. under most circumstances the mutants will need hundreds if not hundreds of thousands of years to overcome selective processes in nature until they really succeed and take over against their natural competitors. This is different with the transgenic crop products: they run through an R&D phase, the transgenesis is done in a targeted way, and the regulatory process takes about 10 to 20 years until the crops are being deregulated. But somewhere along this process they will be propagated to the millions in the field, covering in a evolutionary extremely short time span millions of hectares.

This basic insight of a molecular biologist (more details in (Ammann, K, 2007c) and in print: (Ammann Klaus, 20130415) has been confirmed by analysis of modern breeding processes and their real products in crops, as an example here a comparison on the genomic level between transgenic and non-transgenic wheat traits (Shewry, PR, et al., 2006): conventional plant breeding involves the selection of novel combinations of many thousands of genes, transgenesis allows the production of lines which differ from the parental lines in the expression of only single or small numbers of genes, Consequently it should in principle be easier to predict the effects of transgenes than to unravel the multiple differences which exist between new, conventionally-produced cultivars and their parents.

The above statements are confirmed by other genomic studies (Baker, JM, et al., 2006, Barcelo, P, et al., 2001) – they could be extended to other methods of transformation, such as direct insertion of DNA fragments (Paszkowski, J, et al., 1984) and, with some questions about long term stability, also to the agrobacterium mediated transformations (Maghuly, F, et al., 2007). But what is really interesting in the present context, that it has been demonstrated (Baudo, MM, et al., 2006) that overall, genome disturbances in traditional breeding in comparable cases are measured to be greater than in transformation. It is suggested that the presence of the transgenes does not significantly alter gene expression and that, at this level of investigation, transgenic plants could be considered substantially equivalent to the untransformed parental lines on the genomic level.

In a most recent publication about the same issue, (Batista, R, et al., 2008) the same conclusion is drawn:

"We found that the improvement of a plant variety through the acquisition of a new desired trait, using either mutagenesis or transgenesis, may cause stress and thus lead to an altered expression of untargeted genes. In all of the cases studied, the observed alteration was more extensive in mutagenized than in transgenic plants. We propose that the safety assessment of improved plant varieties should be carried out on a case-by-case basis and not simply restricted to foods obtained through genetic engineering."

On another argumentation line, there are papers published claiming that transgenesis or the insertion of promoters in transgenic plants could be the reason for DNA scrambling mutational disturbances (Latham, JR, et al., 2006), but the publications lack a fundamental demand for such conclusions: a comparison with non-transgenic crops. The same syndrome of lacking comparison applies to another study (Myhre, MR, et al., 2006), claiming that the 35S promoter frequently used to enhance transgene expression is demonstrating some activity in cultures of human cells. The authors just 'forget' to tell the readers, that the very same promoter is part of daily diets including *Brassicaceae* (whether transgenic or non-transgenic).

The consequences of the above are, that organic farming – using the argument of artificial DNA breeding disturbance, should opt for the transgenic crops in specific cases. Another consequence is that transgenic crops of the first generation should never have been subjected to regulation purely based on methodology; rather it would have been wiser to have a close look at the products in each case, as John Maddox already proposed in 1992 in an editorial in Nature (Anonymous, 1992). This is also roughly the view of Canadian regulators (Andree, P, 2002, Berwald, D, et al., 2006). In the case of the Golden Rice this has serious ethical consequences, because each year lost to unreasonable and unscientific regulation causes the hundreds of thousands of deaths due to severe vitamin A deficiency, especially among the children of developing countries of South Eastern Asia. In Europe this kind of unscientific regulatory basis hinders the development of transgenic crop breeding for the benefit of a more ecological production. In particular it hampers public research considerably, and on top of this the organic farming industry does not shy away from false and often hypocritical propaganda against genetically engineered crops for the sake of marketing their own products (Byrne Jay & I., MH, 20121022, Koerth-Baker Maggie, 20130521, Livermore, M, 2012, McHughen Alan, 2013, McHughen Alan, 20130306).

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