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Liberated from Nature or Shackled by It? The Costs and Impacts of Excessive Precaution

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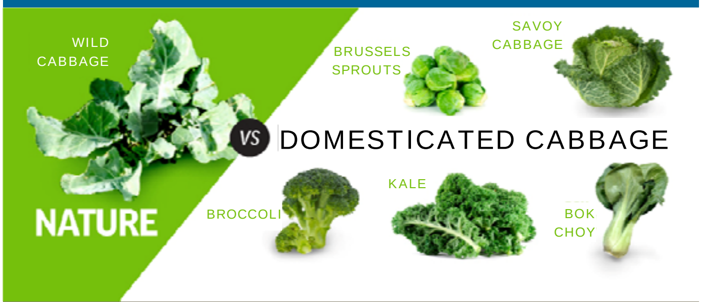
In May 2013, Hollywood star Angelina Jolie announced that she was carrying the hereditary BRCA1 gene mutation and that, as a result, her lifetime risk of breast cancer was 87%.[1] By undergoing a preventive double mastectomy, however, she would reduce her risk to under 5%. Although dramatic, Jolie's story is but one example of the benefits of our ever greater understanding of genes and, increasingly, ability to tamper with them. Interestingly, however, while most people can see the benefits of such interventions in the realm of medical science, they are much more reluctant to make use of this knowledge when applied to agricultural science. They shouldn't be.

TAMPERING WITH THE NATURE OF AGRICULTURE

In all organisms, genetic mutations occur naturally or through exposure to mutagens (physical or chemical agents). Among plants, the appearance of the foliage, flowers, fruit or stems can change drastically over time.[2] Since the beginning of agriculture about 10,000 years ago, humans have profoundly affected the genetic make-up of domesticated plants such as those derived from wild cabbage (Figure 1).[3] All types of fruit, vegetable, and grain that are now commercially available have been bred by the human hands in order to deliver higher yields, better taste, and improved weather and pest resistance.

FIGURE 1

Nature vs. Nurture



Source: GMO Answers. http://gmoanswers.com/explore.

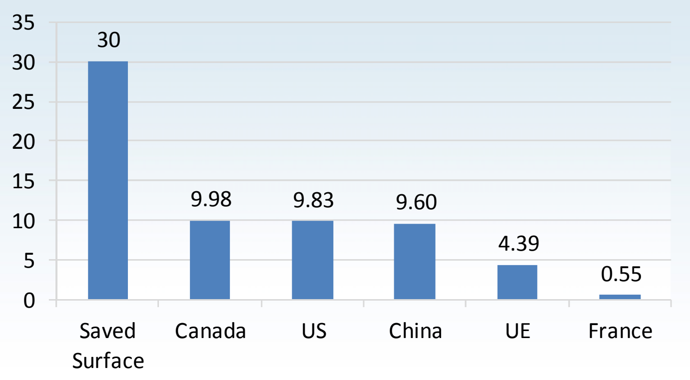
Unfortunately, most urbanites now fail to understand the importance of both biotic stress caused by pests such as animal pests (insects, mites, nematodes, rodents, slugs and snails, birds), plant pathogens (viruses, bacteria, fungi, chromista) and weeds (undesirable plants that compete for resources with cultivars) and abiotic stress attributable to drought, flood, frost, nutrient deficiencies, and soil & air toxicities.[4] For instance, between 2001 and 2003 the most significant global losses attributable to biotic stress among six major crops were because of weeds (34%), animal pests (18%) and pathogens (16%).[5] A 2009 report estimated the global losses due to biotic stress to be about US$ 131 billion and, for weeds alone US$95 billion, about 70% of which occurred in developing countries.[6] Abiotic causes were responsible for between 6 and 20% of agricultural losses.[7]

Agricultural producers have long attempted to protect crops through chemical (fertilizers and pesticides), biotechnological (breeding and genetic fortification) and various management (crop rotations, integrated pest management, production timings and logistics) techniques and practices.[8] The first recorded uses of insecticides and fungicides, such as sulphur compounds and botanical extracts, occurred between 2500-1500 BC. Large scale chemical disease control started in the late 19th century, most notably with the development of products such as Bordeaux mixture that was used for grape protection in French and other vineyards. In the early 20th century, synthetic (or man-made) insecticides were introduced in agriculture, horticulture, stored products, and in public health campaigns.[9] In the latter case, the much-maligned DDT alone is credited with saving more than 500 million lives from malaria and other diseases between 1950 and 1970.[10]

1. Jolie, Angelina. 2013. My Medical Choice, *The New York Times*, May 14. http://www.nytimes.com/2013/05/14/opinion/my-medical-choice.html?ref=opinion.
2. Royal Horticultural Society. Mutations: plant. http://apps.rhs.org.uk/advicesearch/profile.aspx?pid=259.
3. Council for Biotechnology Information. GMO Answers. http://gmoanswers.com.
4. Oerke, E. -C. 2006. Crop losses to pests. *The Journal of Agricultural Science*, 144, pp. 31-43.
5. The six major crops are wheat, rice, maize, potatoes, soybeans, and cotton. Oerke, *op. cit*.
6. FAO. 2009. *Responding to the challenges of a changing world: The role of new plant varieties and high quality seed in agriculture*. The 2nd World Seed Conference report. FAO Headquarters, Rome September 8-10. P. 25 — http://www.fao.org/docrep/014/am490e/am490e00.pdf. For example, aflatoxin (fungi) contamination in staple crops like maize and groundnuts caused African economies losses of about US $450 million a year. See The Consultative Group on International Agricultural Research. 2012. *Annual Report*. P. 15. http://www.cgiar.org/AR2012.
7. FAO. 2005. *Status of Research and Application of Crop Biotechnologies in Developing Countries (Preliminary assessment)*. P. 20. ftp://ftp.fao.org/docrep/fao/008/y5800e/y5800e00.pdf.
8. Oerke, *op. cit*.
9. *Ibid*.
10. National Academy of Sciences. 1970. *The Life Sciences: Recent Progress and Application to Human Affairs, the World of Biological Research Requirements for the Future*, Committee on Research in the Life Sciences, National Academies Press. Washington, DC. Cited in Ames, Bruce N. and Gold, Lois Swirsky. 2000. Paracelsus to parascience: the environmental cancer distraction. Mutation Research, 447, pp. 3-13.

FIGURE 2

Importance of land saved thanks to progress and increased productivity in agriculture, 1960-2010 (million km²)



Sources: Jesse H. Ausubel, 2012, *op. cit.* ; The World Bank.[11]

In 1961, the United States Department of Agriculture (USDA) registered Bacillus thuringiensis (Bt), a natural bacterium which produces toxic crystal proteins, as the first biological pesticide.[12] Bt was first sprayed on crops and, being completely "natural," is still widely used by organic producers. In 1995, the first genetically engineered Bt crops (in which the plants themselves contain Bt) were approved by the United States Environmental Protection Agency (EPA).[13] Environmental activists who approve of Bt being sprayed on crops, however, were and are still strongly opposed to this technological advance.

Another significant advance attributable to genetic engineering (or more accurately recombinant DNA (rDNA)) technologies are herbicide resistant crops (most prominently soybeans and maize) that allow agricultural producers to better eliminate weeds that compete for water, nutrients and sunlight.[14]

From 1996 to 2012, the world's area devoted to biotech crop increased 100-fold from 1.7 million to 170 million hectares (one hectare is about the size of a rugby field), more than 2.5 times of size of France.[15] Of the 15.4 million farmers using rDNA species in 2010, more than 90% were small-scale and resource-poor farmers in developing countries who benefit from greater protection against biotic and abiotic stress, and less exposure to pesticides than would otherwise be the case.[16]

Overall, rDNA crops have significantly reduced pesticide and herbicide use.[17] From 1996 to 2011, biotech crops eliminated the need for about 473 million kilograms (kg) of pesticides and their higher productivity also meant that they saved about 108.7 million hectares of land.[18] In combination with other means and approaches, they have improved the quality and quantity of harvests while using much less resources per unit produced. In 2011 alone, they reduced CO_2 emissions by 23.1 billion kg which is equivalent to taking 10.2 million cars off the road.[19]

To get a sense of the significant health, nutritional and environmental benefits of agricultural advances in the past 50 years, suffice it to say that while the world population more than doubled, agricultural production almost tripled while the cultivated area only grew 12%.[20] According to a recent estimate, since the 1960's the land spared (because it was not needed) through increased yields was comparable to the surface area of the U.S., Canada, and China combined (see Figure 2).[21] While modern agricultural technologies and management practices are not perfect, they have delivered significant social and environmental benefits over previous crops and practices.

A "second generation" of rDNA crops now promises to improve the nutritional quality of foods by adding vitamins, minerals, proteins and antioxidants (e.g., Pineapple with high lycopene);[22] reducing toxic compounds (e.g., cassava with less cyanide, low acrylamide potatoes); reducing allergens (e.g., groundnuts and wheat); increasing healthy Omega-3 fatty acids; and improving the preservation of fresh foods.[23] For example beta-carotene (a precursor of vitamin A) fortified rice, better known as "golden rice," can alone prevent 1-2 million deaths and blindness in around 500,000 children each year.[24]

Many prominent regulatory and scientific organizations have stated that rDNA engineered plants are safe for consumption and present no adverse environmental effects.[25] These assessments

11.The World Bank, "Surface area," available at: http://data.worldbank.org/indicator/AG.SRF.TOTL.K2 (page visited in October 2013).
12. International Food Information Council Foundation. Food Biotechnology Timeline. http://www.foodinsight.org/LinkClick.aspx?fileticket=PxuyvFzzqCE%3D&tabid=1476.
13. Oerke, *op. cit*.
14. For more details on Bt and Bt crops, see Jabr, Ferris. 2013. Farming a toxin to protect crops, pollinators and people. *Scientific American*. September 03. http://www.scientificamerican.com/article.cfm?id=farming-a-toxin.
15. The International Service for the Acquisition of Agri-biotech Applications (ISAAA). 2012. *Global Status of Commercialized Biotech/GM Crops: 2012* (Executive Summary). http://www.isaaa.org/resources/publications/briefs/44/executivesummary/.
16. *Ibid*.
17. Information on genetic engineering technology at the International Service for the Acquisition of Agri-biotech Applications (ISAAA) site at http://www.isaaa.org/resources/publications/default.asp.
18. The International Service for the Acquisition of Agri-biotech Applications (ISAAA), *op. cit*.
19. Feslot, Allan S. *Pesticide & Health: Myths vs. Realities*. American Council on Science and Health. Position paper.
20. *Year Book 2013*: World Food and Agriculture. Rome. http://www.fao.org/economic/ess/ess-publications/ess-yearbook/en/#.Ul8SjlZzbIU.
21. Interview article with Jesse H. Ausubel: Rockefeller University News Wire. 2012. Changes in population growth, consumption and farming begin to return former farmland to nature. *Science News*. December 21. http://newswire.rockefeller.edu/2012/12/21/changes-in-population-growth-consumption-and-farming-begin-to-return-former-farmlands-to-nature/.
22. The Council for Biotechnology Information. GMO Answers. http://gmoanswers.com/.
23. FAO. 2004. *State of Food and Agriculture 2003-4: Agricultural Biotechnology, Meeting the need for poor?* Chapter 5. Health and environmental impacts of transgenic crops: International Food Information Council Foundation, Fact Sheet: Benefits of Food Biotechnology, May 13, 2013. http://www.foodinsight.org/Resources/Detail.aspx?topic=Fact_Sheet_Benefits_of_Food_Biotechnology.
24. FAO. 2009. *Responding to the challenges of a changing world: The role of new plant varieties and high quality seed in agriculture*. The 2nd World Seed Conference report. FAO Headquarters, Rome, September 8-10. P. 26.
25. The Grocery Manufactures Association. The Facts about GMOs. http://factsaboutgmos.org/disclosure-statement.

recognize the fact that these new crops have been more extensively tested than varieties developed through older methods.[26] Opposition to rDNA crops ultimately rests not on tangible evidence, but on hypothetical risks and a lack of historical perspective.

NATURAL VS. SYNTHETIC CHEMICALS

Rachel Carson's 1962 best-seller *Silent Spring* warned of the dangers of man-made chemicals that were allegedly killing birds, increasing cancer rates, and wreaking havoc on the balance of nature. Yet, Carson's premise that molecules created through "natural" processes are always more beneficial or less damageable than synthetic ones was never based in facts.

Carcinogens: natural vs. man-made chemical

Because they cannot outrun their predators, one of plants' main means of defense is the production of toxic substances. Some of these can create paralysis, liver damage and even death among humans. Among some of these completely natural substances are cyanide (cassava root, almond nut, and cherry, apricot, plum's pit, apple seeds), alpha-amanitin (wild mushrooms), linamarin (Lima beans), phytohaemagglutinin (Kidney beans), and solanine (potato).[27]

« Fears of new technologies have resulted in ever more significant regulatory costs and delays. »

Consuming these foods is not problematic provided that they are produced and prepared properly. Failures in the chain of production and preparation, however, can be problematic. For instance, zucchinis caused a significant food poisoning outbreak in New Zealand in 2003 when an organic farmer used older ("heirloom") varieties and refused to spray pesticide on them. Confronted by predators, the zucchinis produced much higher levels of toxins than would have otherwise been the case, something which would have never occurred if the farmer had used more recent varieties and conventional pesticides.[28]

The main fear associated with synthetic chemicals is that they are carcinogenic. Yet, countless naturally produced substances are also carcinogens. According to a classic study, 99.99% of the toxic chemicals we ingest everyday are the natural pesticides produced by plants.[29] An average American thus ingests daily about 1,500 mg of 5,000 to 10,000 varieties of natural pesticides, about 750 mg of which were found to be rodent carcinogens in laboratory tests. By contrast, the daily intake of primary synthetic pesticide residues is about 0.09 mg per person while a single cup of coffee contains about the same amount of rodent carcinogens as an average human's annual intake of synthetic pesticide residues.

Despite widespread fears of modern technologies and synthetic pesticides, cancer risks from synthetic pesticide residues are practically nonexistent while both cancer incident and death rates have been falling in the United States.[30] According to the American Cancer Society, exposure to carcinogenic agents in occupational, community, and other settings accounts for a small percentage of cancer deaths — about 4% are from occupational exposures and 2% from environmental pollutants (both man-made and naturally occurring). The real causes of cancer are smoking (30%) and a combination of poor diet, physical inactivity and obesity (35%).[31]

As prominent scientists Ames and Gold have argued, pursuing a toxic chemicals and risk free world is impossible while aiming to eliminate minuscule concentrations of carcinogenic substances that can only be measured through advanced 21st century technologies is a costly and ultimately futile endeavor.[32]

DEATH BY STAGNATION AND RED TAPE

Fears of new technologies have resulted in ever more significant regulatory costs and delays. For instance, the average development and registration times for new pesticides in 2005-8 were 9.8 years (up 15% since 1995), while the costs reached US$ 256 million, 11 times what they were between 1975-1980.[33]

These rising costs are to a large degree the result of complex and onerous regulatory requirements. From 2008 to 2012, the world average cost for commercializing a new genetically engineered crop was US$ 136 million, about US$35 million of which served to meet regulatory constraints.[34] Needless to say, these additional costs often brought on by activist demands constitute

26. GMO Answers. Public review. http://gmoanswers.com/public-review.
27. Detailed lists at Environmental graffiti. 10 every fruits and vegetables that are poisonous. http://www.environmentalgraffiti.com/news-10-poisonous-fruits-and-vegetables.
28. DeGregori, Thomas R. 2003. The Plant Protection Racket: Inferiority as a Luxury Item. *Butterflies and Wheels*. September 11. http://www.butterfliesandwheels.org/articles/page/29/.
29. Ames, Bruce N. and Gold, Lois Swirsky. 2000. Paracelsus to parascience: the environmental cancer distraction. *Mutation Research*, 447, pp. 3-13.
30. National Cancer Institute. http://www.cancer.gov/newscenter/newsfromnci/2013/ReportNation.
31. American Cancer Society. 2013. *Cancer Facts & Figures*. p.47.
http://www.cancer.org/acs/groups/content/@epidemiologysurveilance/documents/document/acspc-036845.pdf.
32. Ames and Swirsky, *op. cit*.
33. McDougall, Phillips. 2010. *The Cost of New Agrochemical Product Discovery, Development & Registration and Development and Research Predictions for the future*. Crop Life America, January.
http://www.croplifeamerica.org/phillipsmcdougallstudy.
34. The cost for major 6 international companies: BASF, BAYER, DOW, Dupont, Monsanto, and Syngenta AG. McDougall, Phillips. 2011. *The cost and time involved in the discovery, development and authorisation of a new plantbiotechnology derived trait.* R &D report. Crop Life International. November 7. http://www.croplife.org/search/s?q=R%26D_costs.

a powerful barrier to entry in an industry which activists often decry as excessively concentrated in the hands of a few corporations.

While a case can be made that wealthy societies can afford to be excessively cautious, the situation is different in less developed ones. For instance, in 2010 about 219 million cases and an estimated 660,000 deaths (mostly children) were attributed to malaria.[35] In sub-Saharan Africa and other poor locations, many people can't afford expensive mosquito control methods while significant roadblocks have been put in the way of the most cost-effective vector-control mean available, DDT.

In 2011-13, a total of 842 million people (about one human in eight) were thought to suffer from chronic hunger (i.e., a lack of food that prevented them from leading an active life),[36] yet opposition to genetic engineering crops in some advanced economies means that only four African countries (Burkina Faso, Egypt, Sudan and South Africa) had adopted them because of the fears that Europeans would stop purchasing local agricultural exports.[37]

CONCLUSION: BETTER LIVING THROUGH SUPERIOR TECHNOLOGIES

The Eurobarometer survey reveals poor knowledge of molecular biological techniques and ambivalent attitude towards them based on their application (e.g., favorable to medical gene therapy, but unfavorable to agricultural advances) and various moral concerns.[38] Popular perceptions, in turn, have been shaped in large part by well-funded opposition to technological advances. For example, Greenpeace's annual income is about EUR 241 million, 98% of which came from 2.9 million mostly upper middle class individuals who often live in fear of demonstrably beneficial advances such as child vaccination and plastic bottles.[39]

The activists' rhetoric has increasingly promoted the superficially unobjectionable "precautionary principle" in which no innovations are allowed in the absence of absolute certainty regarding possible harm. In practice, however, the absolute absence of anything potentially harmful is a poor guide to public policy in a world where there are no harmless chemicals, but only harmless uses of chemicals.

While no innovation can ever be perfect, our key concern should be whether or not it creates lesser problems than those that existed before. By contrast, the seemingly sensible "no risk" precautionary principle effectively bans better and less damaging ways of doing things, like application of chemicals and biotechnology in agricultural systems, and as such comes at a significant social, environmental and economic cost.

Would Angelina Jolie have been better off if her grandmother's generation had blocked technological advances because of potential risks and fears of the unknown? Obviously not. As she observed: "Life comes with many challenges; the ones that should not scare us are the ones we can take on and take control of."[40]

35. World Health Organization (WHO). *Malaria Fact Sheet* No 94. http://www.who.int/mediacentre/factsheets/fs094/en/.
36. FAO. 2013. *The State of Food Insecurity in the World 2013*. Executive Summary. P. 1. http://www.fao.org/docrep/018/i3458e/i3458e.pdf.
37. The Alliance for a Green Revolution in Africa (AGRA). 2013. *Africa Agriculture Status Report*. P. 63. http://www.agra.org/our-results/annual-reports/.
38. Pechan, Paul and Vries, Gert E. de. 2005. *Genes on the Menu: facts for knowledge*. Berlin: Springer. P. 137.
39. Greenpeace. *Annual Report* 2011. http://www.greenpeace.org/international/Global/international/publications/greenpeace/2012/AnnualReport2011.pdf ; Bailey, Ronald. Top 5 Bogus Health Scares. *Reason*. August 9. http://reason.com/archives/2013/08/09/the-top-5-bogus-public-health-scares.
40. Jolie, Angelina, *op. cit.*

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