Open-source Agriculture

C. Neal Stewart, Jr.

Computer software is amenable for duplication, modification, and improvement and therefore has greater utility and value … DNA as well. Sharing software freely has enabled the open-source movement and has led to numerous innovations in operating systems and products. What about open-sourcing DNA—is that the key to agricultural innovation and feeding an ever-growing population?

One person who thinks so is Richard Jefferson, of GUS reporter gene fame, who is the director of CAMBIA (http://www.cambia.org) and its new offshoot, BiOS (Biological Innovation for Open Society, http://www.bios.net/daisy/bios/15). BiOS and other organizations such as PIPRA (Public Intellectual Property Resource for Agriculture; http://www.pipra.org) are promoting open access to biological innovations targeted to agricultural improvement, especially for crops most important to the developing world.

Currently there are relatively few companies, located mainly (about 75%) in the private sector,[1] that hold patents on crucial agricultural biotechnologies; however, Jefferson believes those few companies could be using those patents to "dominate then destroy an industry." Alternatively, he is advocating parallel engineering—that is, the creation of redundant inventions to endow freedom to operate.[2] A perfect example of this is the TransBacter system—the 'new Agro'[3]—in which bacteria other than *Agrobacterium tumefaciens* were shown to transfer DNA stably into plant genomes. Indeed, CAMBIA is providing free access to *Sinorhizobium meliloti*, *Mesorhizobium loti*, and *Rhizobium* sp. NGR234 as *Agrobacterium* alternatives. Much work remains to increase the transformation efficiency provided by these bacteria, but the research is seminal. CAMBIA allows researchers to use these bacteria for free in non-profit and for-profit research and product development; but, in return, the recipient must pledge to make any subsequent improvements freely accessible to others.

Typically when a company makes an invention, it files for a patent and does not freely share the invention—whether it be a promoter, gene, transformation tool, or any other enabling technology. Companies do not share because a patent will allow them to recoup any investment they have made on the invention, as well as secure an exclusive use of the technology for 20 years, when the patent runs out. Of course, they might elect to license the technology to other parties, as DuPont does for biolistic-mediated plant transformation, if it appears that the licensee will not be a direct competitor. Herein lies the difference: status quo is protective and open source is disseminative. The former rests on free market economic forces, while the latter is dependent on altruism and the future gambit that participants will benefit from collective access to improvements

The poster child for open-source agriculture is 'Golden Rice', which is engineered to contain elevated provitamin A content.[4&5] The researchers' intentions were to make this rice seed freely available to farmers in the developing world to combat dietary vitamin A deficiency and the childhood blindness that often results. To do so, they literally sweet-talked and shamed patent holders into allowing the technologies, which were restricted by myriad intellectual property rights, to be available, and so enabled a path for Golden Rice to be marketed. Someone looking at the development of Golden Rice might ask the obvious question: if patent holders do not make agricultural biotechnology tools freely accessible, how do researchers like those working on golden rice get them in the first place? The answer is that companies often *do* make these tools freely accessible for research in a roundabout way. All plant biotechnology researchers have disarmed *Agrobacterium*, the 35S promoter, and the *nptII* antibiotic resistance gene in their labs and use them for plant transformation research. These tools get passed around informally from group to group, with the patent holders opting not to block this type of non-profit research. However, it is when the technologies are used in commercial products that patent holders make a stink. Open-source would be more fragrant in that regard.

The question then becomes, would open-source really be effective in facilitating commercialization and technology transfer that could help the poorer farmers of the world? There is no simple answer. Perhaps smaller companies would benefit from open-source biotechnology, because they could then have a chance to play. However, substantial federal and state regulations for products of agricultural biotechnology pose significant barriers for all but the largest of companies. Simply put, many companies wishing to sell transgenic seed will not likely have the millions of dollars needed to meet current regulatory requirements. Regardless whether products were intended for cultivation in the U.S. or Pakistan, for example, the initial regulatory costs might easily outweigh the intellectual property costs. We can hope, however, that regulatory hurdles will eventually be relaxed, as biosafety concerns are assuaged by time and track records—at least for agronomic traits that are becoming very familiar stories in agricultural biotechnology. Value added and output traits might not see regulatory slack for decades. Still, for certain traits and crops, open-source and open-access agriculture has merit.

PIPRA is comprised of a consortium of non-profit research groups—mostly located at land grant universities—committed to making "agricultural technologies more easily available for development and distribution of subsistence crops for humanitarian purposes in the developing world and specialty crops in the developed world" (http://www.pipra.org). Thus, the PIPRA model can be distinguished from open-source: PIPRA seeks to collaborate with member institutions on intellectual property policy, organize a public-sector intellectual property database, and develop shared technology packages.[6] PIPRA has positioned itself to work with university technology offices to walk the tightrope between optimal commercial return and optimal humanitarian benefit. Whereas open-source is focused on cumulative improvements, PIPRA seeks to package public sector-derived technologies to support innovation in crops grown in developing countries.

In addition to regulatory hurdles and organizational constraints, there is a dearth of public science that can enable agricultural innovation relevant to the poorer farmers of the world. Even if the TransBacter system is not proved to infringe on broad patents, there are other crucial pieces of science and technology needed to commercialize transgenic plants. For example, genes of interest, promoters, and marker genes are all needed to provide a complete package for freedom-to-operate scenarios. And then there are other technologies that might be useful on the regulatory end, such as recombination tools that could deliver transgenic plants enabled to contain their transgenes in space and time.

Solving these problems starts and ends with funding, since there is little else to limit the willing and able plant scientists with records of innovation. Other than a few foundations to support biotechnology for developing countries and the meager public funding in the developing countries themselves, there is little interest in funding the research needed to make a real difference. The plant ABC transporter that confers kanamycin resistance to transgenic plants[7] was discovered serendipitously en route to completing a project funded by the U.S. Army. I personally would much rather work for explicit humanitarian purposes at the onset of a project. Indeed, a concerted effort to discover other selectable markers and promoters is needed, along with deep pockets for funding. The same is true for gene containment technologies. Indeed, commensurate with funding, it would be desirable to guarantee that research would be available for open-source or open-access platforms before discoveries are made. A few researchers are already engaged in this paradigm. PIPRA is involved in the production of a plant transformation vector, with components obtained from the public domain and its member institutions, which is intended for royalty-free use for humanitarian purposes.

Whether the CAMBIA/BiOS, PIPRA, or some other organization ultimately succeeds in facilitating increased access to the biotechnological tools of agricultural science, the beginning of the 21st century should be noted for initiating these important steps toward agricultural equity between North and South. Who knows what will eventually work, but matters as weighty as political instability, mass starvation, and world economic depression could weigh in the balance of the eventual outcome.

Acknowledgement. *Thanks to Sara Boettiger for reviewing and discussing an earlier version of this article.*

References

1. Graff G D *et al.* (2003) The public-private structure of intellectual property ownership in agricultural biotechnology. *Nat Biotechnol* **21**, 989-995
2. Herrera S (2005) Profile: Richard Jefferson. *Nat Biotechnol* **23**, 643
3. Broothaerts *et al.* (2005) Gene transfer to plants by diverse species of bacteria. *Nature* **433,** 629-633
4. Ye X et al. (2000) Engineering provitamin A (b-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm. *Science* **287,** 303-305
5. Potrykus I (2001) Golden rice and beyond. *Plant Physiol* **125,** 1157-1161
6. Atkinson R C et al (2003) Public sector collaboration for agricultural IP management. *Science* **301,** 174-175
7. Mentewab A & Stewart C N Jr. (2005) Overexpression of an *Arabidopsis thaliana* ABC transporter confers kanamycin resistance to transgenic plants. *Nat Biotechnol* **23**, 1177-1180

C. Neal Stewart, Jr.
University of Tennessee, Dept. of Plant Sciences
Knoxville, TN
nealstewart@utk.edu