
Bringing Biotech Potatoes to Market

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J.R. Simplot is a privately held \$6 billion company, with 10,000 employees. We mine phosphate and manufacture fertilizers that we sell to farmers. We've been a longstanding potato producer in the United States, and we're involved in livestock. Plant-biotechnology work was initiated in 2001 with a few scientists. Our mission is to create safe, healthy, sustainable crop improvements with a focus on potato. We now number about 65 and are in the comment period for our first regulatory submission. We will petition for our second-generation biotech crop in six to eight months; our objective is to bring multiple products to market.

BUILDING ON BIOTECH

Building a biotech business involves a lot more than science. Certainly, commitment to good science is essential. Obtaining proprietary technology is often a necessary part of R&D. The regulatory side requires submission of sufficient, but not excessive, data. And business development includes determination of the value of the trait in question, and building marketplace acceptance. Potato production involves four sub-industries. Each is large and comprises varied players, therefore good marketing is essential to build general acceptance. The last component is commercialization. It is one thing to obtain regulatory approval, but it takes much effort and many trials to bring farmers along; much more is involved than running regulatory trials for the USDA.

This area of endeavor is not without controversy and your company culture must inculcate willingness to address such controversy with awareness that you won't be everyone's best friend all the time.

INNATE TECHNOLOGY

Our marketing effort involves talking about our Innate™ technology:

An innovative biotechnology approach to improving crops using a process that uses plant genes to enhance desirable traits and reduce less desirable ones.

Innate™ is a way of putting a plant's own genes back into a plant. We needed a way to introduce our biotech approach to the potato industry and eventually to consumers. As part of our market research, we tested several messages and created Innate™ Brand as a face for new plant-biotechnology processes for improvements in crops and foods. Innate™ provided a way to talk about our technology without resorting to the less consumer-friendly terms, intragenic and cisgenic.

We take DNA that elicits either expression of (a) desirable trait(s) or less expression of (a) less-desirable trait(s) from a cultivated variety or from a wild-species progenitor potato, and put it back into Russet Burbank to produce an Innate™ Burbank (Figure 1). This is the level at which we want to communicate the technology, both to growers and to consumers.

MARKET RESEARCH

We've done a lot of market research that shows that results depend on how questions are worded. However, with enough studies, trends emerge. The data in Figure 2 demonstrate potential consumer acceptance of the Innate™ technology—having explained that it is a

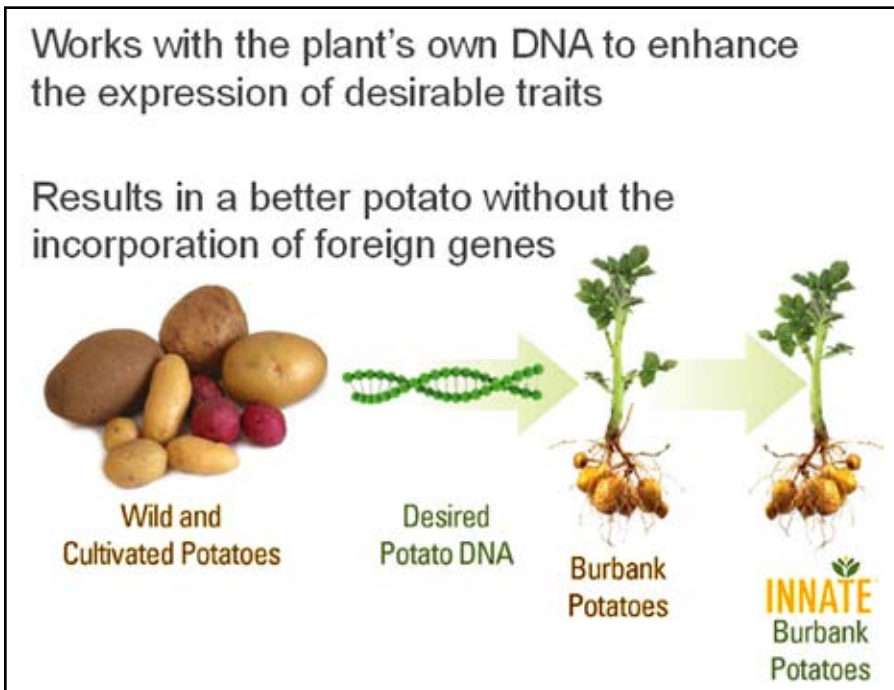


Figure 1. Innate™ technology: How it works.

plant-based gene transfer—in comparison with genetically modified, traditionally bred, and “biotechnology” counterparts. It is noteworthy that use of the word “biotechnology” elicits greater comfort among consumers than “GMO.” Explanation of the Innate technology produced acceptance close to that of plant breeding, but not quite there. Our goal is not to be acceptable to everybody, but to be as acceptable as plant breeding, and, clearly, we are close, which is a promising message for all using molecular genetics for crop improvement, *i.e.* consumer acceptance of the technology is potentially good.

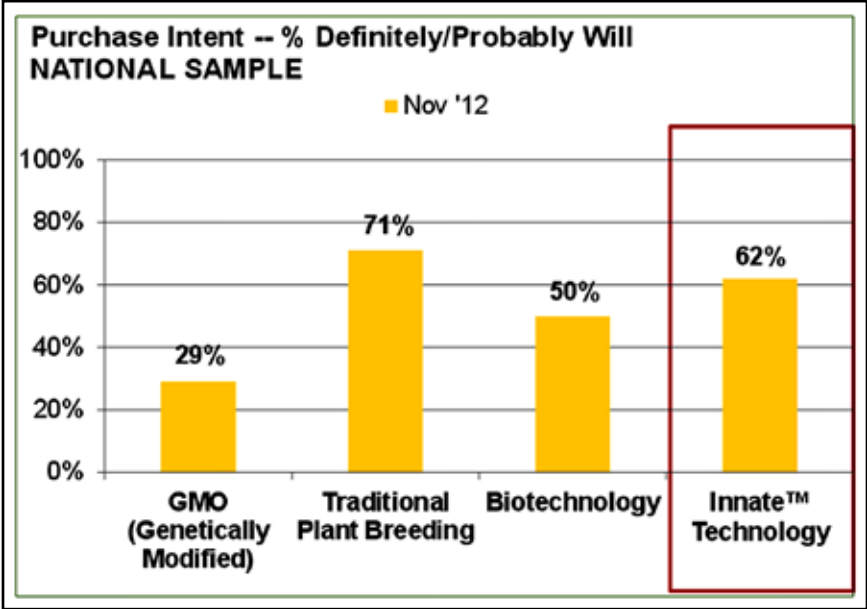


Figure 2. Survey: How likely would you be to purchase fruits and vegetables that are improved using Innate™ technology?

FIRST GENERATION OF TRAITS

Traits we are bringing to market using “Innate 1.0” potato are:

- Reduced black-spot bruise, and
- Reduced asparagine.

Reduced black-spot bruise is a trait similar to non-browning in the Arctic apple.¹ We had to silence only one of the five or six polyphenol oxidase (PPO) genes, PPO 5 in a tuber-specific manner. And we have down-regulated asparagine in tubers—again tuber-specific—by silencing asparagine synthase. Instead of asparagine—a precursor of acrylamide—the modified tuber accumulates glutamine, so the nitrogen content stays relatively similar and yield is unaltered, which was an unexpected benefit. If asparagine synthase is silenced throughout the plant constitutively, growth is compromised.

¹Pages 87–94.

Four varieties have been improved via Innate 1.0: Russet Burbank, Ranger Russet, Atlantic and Snowden. Russet Burbank and Russet Ranger are the primary French-fry varieties, and Atlantics and Snow are the primary varieties used to make chips. The improvements result in benefits to growers, processors and consumers. Browning occurs not only after cutting (Figure 3), but also when stacked in storage, which causes pressure bruising. Usually, tissue change is minimal, but it does occur and is a significant problem in the fresh market. In the French fry and chip industries, brown potatoes are removed and used for cattle feed; the grower is penalized and the processing plant loses productivity.

Acrylamide occurs naturally and is present in almost all baked and fried foods. It forms at around 300°F. California has a labeling requirement for baked or fried potato products containing acrylamide above 300 ppb. In response, some companies mitigate the problem via enzyme use, whereas other companies have withdrawn their products from the market in California. Figure 4 shows that potato chips made with Atlantics accumulated acrylamide at 450 ppb, whereas Innate™ Atlantics contained acrylamide at 130 ppb. Similar patterns were found with French fries made with Russet Burbank and Ranger Russet and their Innate™ counterparts (Figure 4).

Two ingredients contribute to acrylamide formation: asparagine and sugars. We control only the asparagine component in the first generation of Innate™ potatoes, and, in general, we see reductions in acrylamide content of 50% to 70%.

A key ancillary question: *Could the benefit of lowering acrylamide overcome opposition of biotech?*

UNIFORMITY

Those whose job is to improve potatoes, and who are focusing on the farmer, are missing 80% of the potential. Downstream companies that make products from potatoes are the big sellers. Farmers produce \$3.5 billion worth of potatoes every year, whereas somewhere around \$40 billion worth of French fries are sold. The market is controlled by customers who demand uniform quality in their French fries and chips. Figure 5 shows a spidergram containing a 15-point hedonic scale. Innate™ potato products must give data identical to their non-Innate counterparts in terms of performance from a sensory perspective, aroma, crispness, toughness, *etc.* Although we've affected the asparagine content and the PPO, we have not affected starch pathways or other metabolism that affect sensory perception, which is a major consideration for our customers.

Figure 6 shows field data for Innate™ Russet Burbank in comparison with its parental counterpart; these trials are expensive to run. Each comprises an acre or two, and yield-tracking data are generated using modeling software. We've done this a number of times and find consistently that there is no difference between Burbank and Innate™ Burbank (E12), and that's important because some farmers have been led to believe that yield "drag" results from biotech traits.

SECOND AND FUTURE GENERATIONS

In 2013, we are running over 30 field trials across the United States and Canada, including a commercial development trial in Texas. We encourage growers to visit our commercial



Figure 3. Comparison of an Innate™ potato (left) and a traditional potato 10 hours after being cut.

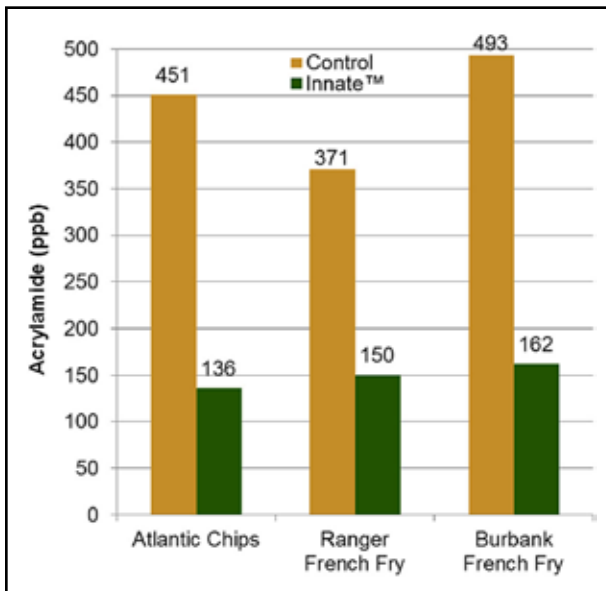


Figure 4. Simplot research, 2012.

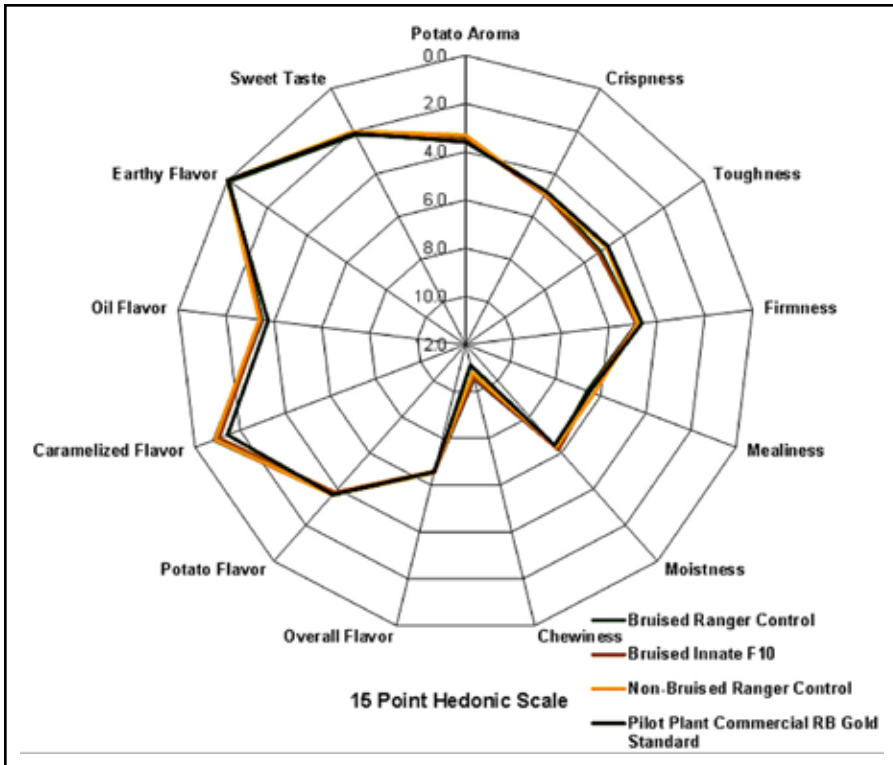


Figure 5. Spidergram: Ranger Russet and Innate F10 Ranger Russet comparisons with Russet Burbank gold standard—no sensory differences.

trials. Also, we have advanced regulatory trials for the next generation of Innate™ potatoes. Figure 7 shows the traits that we are working on.

Generation 1.0 will comprise low asparagine and low bruising as mentioned, and less sugar when harvested. Our projection is to launch Generation 1.0 in 2015. We expect to launch Generation 2.0 in 2017 and, to that end, we are working on a gene that provides sugar control. Potatoes are stored at between 48°F and 52°F, sometimes at 46°F. That temperature is one of the single most important economic drivers in the potato industry. The gene that we’re working on for sugar control allows storage at 38°F, at which several post-harvest issues are circumvented because of less disease. We have licensed a gene from Jonathan Jones’ lab—the *vnt1* gene—for broad resistance to strains of *Phytophthora infestans*, which causes late blight. In our research pipeline we are also working on resistance to potato virus Y (PVY), on improvements in use efficiencies of water and nitrogen, on enhanced vitamin content and on improved tuber set.

Figure 8 demonstrates positive effects of the Innate™ 2.0 technology on fresh-potato quality. As a result of storage at 38°F, zebra-chip discoloration (top left), caused by *Liberibacter* spp. is decreased. And dark “sugar ends” (bottom left)—caused by a high concentration of reducing sugars—are alleviated by silencing the gene encoding invertase.

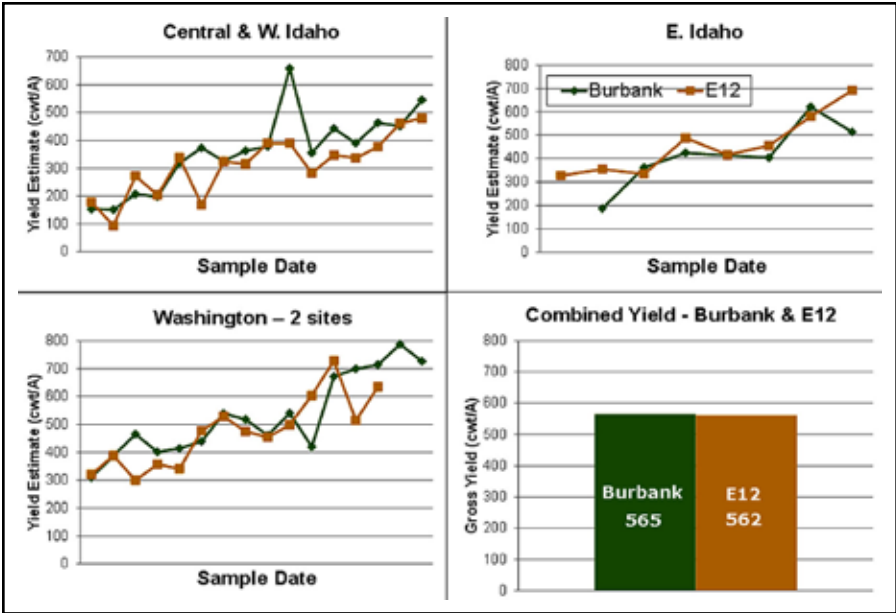


Figure 6. Russet Burbank and Innate™ E12 yield comparisons

Innate™ 1.0 2015 Launch	Innate™ 2.0 2017 Launch	Future Traits 2018+
<ul style="list-style-type: none"> • Low Asparagine • Low Bruise • Lower Sugars at Harvest 	<ul style="list-style-type: none"> • Sugar Control • Cold Storage • Sugar Ends • Late Blight • Low Asparagine • Low Bruise 	<ul style="list-style-type: none"> • PVY • Water Efficiency • Nitrogen Uptake • Enhanced Vitamins • Tuber Set

Figure 7. Future Innate™ traits.

Atlantic is an 85-day potato, whereas most others have a growing season of 110 to 140 days. For this reason, Atlantics are grown all over the world, even though they don't store well; they build sugars too quickly, which causes browning that no one wants. Resistance to browning after six months at 38°F means a lot to farmers (Figure 9). The 25,000 thousand acres of Atlantics that are grown in the United States must be shipped to processing plants a day or two after they are dug. The Innate™ technology will expand the acreage of this variety relative to a number of others.

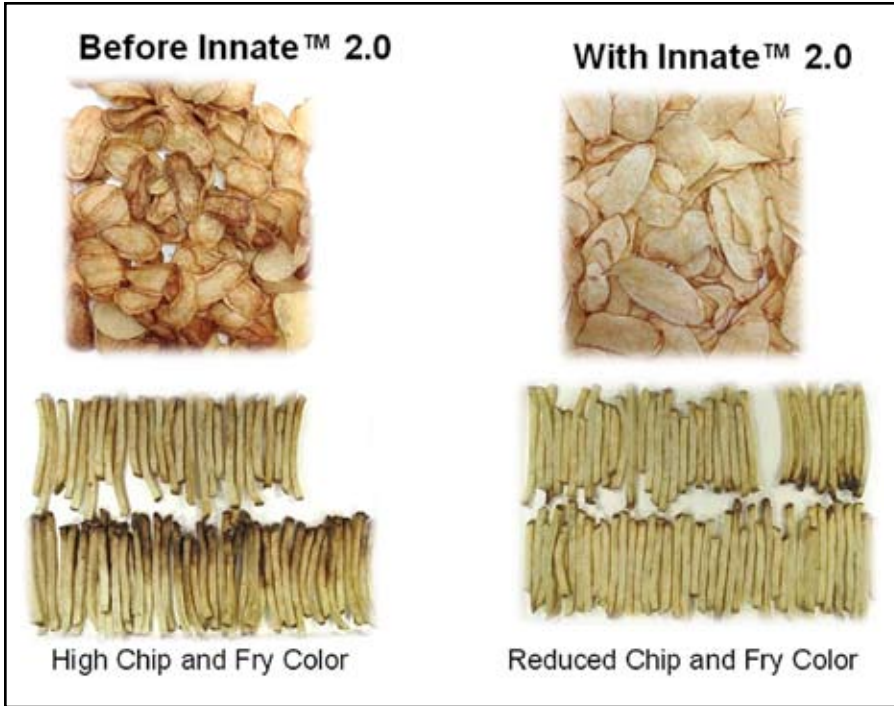


Figure 8. Innate™ 2.0: Impact on fresh-potato quality.

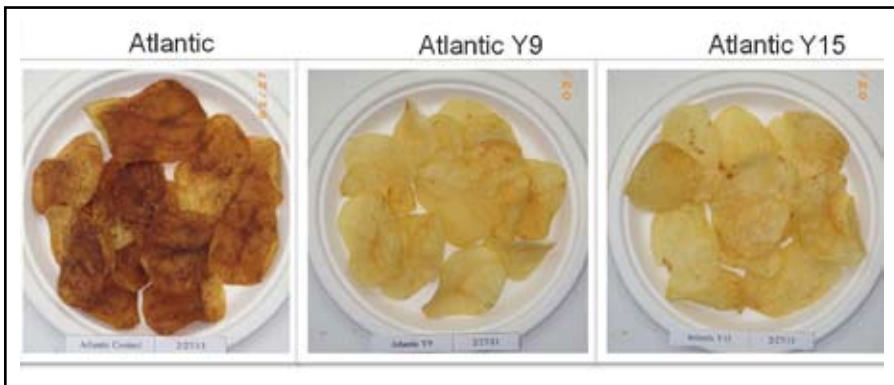


Figure 9. Innate Atlantic 2.0 lines Y9 and Y15 fry with reasonably good color after six months of storage at 38°F.

REGULATORY AND BUSINESS CONSIDERATIONS

If you create a new potato through biotechnology, using only potato genes, how are you regulated? If you used agrobacterium, you're regulated by the USDA. If you have a novel trait, you'll be regulated by Canada, and if you use recombinant DNA, you'll be regulated

by Japan. Whether the technology is cisgenic or intergenic, it will be treated the same as GM in Europe. New TALEN² technology has exciting potential, but it is possible that deregulation will be needed to protect export markets. We believe that, over the coming 25 years technology improvement will move back in the direction of transgenics, having used within-species manipulations to gain consumer acceptance of genetic approaches. Although we are committed to our Innate[™] technology, we keep an open mind and avoid disparagement of other technologies.

Figure 10 represents our projected regulatory timeline. At this point, June 2013, we are in a public-comment period from which we expect deregulation of Innate Russet Burbank 1.0, Innate Russet Ranger 1.0 and Innate Atlantic 1.0 in 2014, and that these three products will be on the market in 2015. If we are lucky, Innate[™] potatoes from the 2014 growing season will be included as ingredients in products available to consumers in 2015. In 2016, we expect deregulation of Innate[™] 2.0 products, with commercial introductions of Innate Russet Burbank 2.0 and Innate Ranger Russet 2.0 in 2016 and 2017, respectively. Deregulation of Innate[™] 3.0 technology will be applied for in 2018.

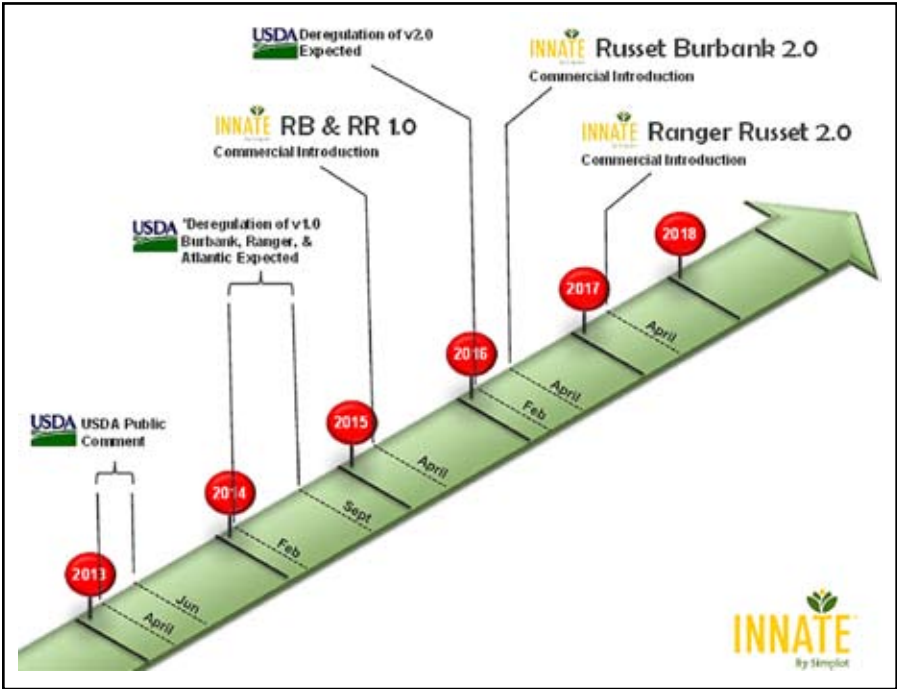


Figure 10. Innate[™] timeline.
 (*There is no guarantee that the USDA will deregulate Innate[™] potato products.)

²Transcription activator-like effector nuclease.

IDENTITY PRESERVATION

From the point of view of identity preservation, potatoes have important inherent advantages:

- Potatoes are largely self-pollinating. The flowers have no nectar, and are not visited by insects. Separation by 20 m is sufficient to eliminate the risk of outcrossing.
- Potatoes are clonally propagated from tubers, not grown from seed.
- Lines can be easily distinguished with PCR.

BUSINESS CHALLENGES

The potato market comprises several segments:

- Chips,
- Frozen products (French fries and hashbrowns),
- Fresh potatoes, and
- Dehydrated potatoes.

Each of these entities is supplied to the consumer as different varieties by separate industry players. Satisfying the needs of producers presents a challenge to the potato supplier. Regulatory approvals *vis-à-vis* international markets represent another challenge. The capital that needs to go into seed potatoes is another issue. The value of US potatoes at the farm gate is \$3.5 billion, which represents an initial investment of \$350 million. Seed-potato cost runs at \$400 dollars per acre if not more, which is expensive.

Another issue is the variety of varieties. With eight varieties, we believe that we can capture 60% of the potato market. To get to 90% would require double that, and, since backcrossing is impossible, each event has to be deregulated. Of course, it will be impossible to capture the whole potato market. Our goal is to capture the majority of the chips and the frozen and fresh markets; we expect to leave specialty potatoes to competitors.

Another challenge is the traditional business model for biotech (Figure 11). Critical aspects are how much the trait improves the crop and market penetration, *i.e.* how many acres; those two are multiplied together to calculate the revenue. If the crop is improved by \$100 dollars an acre, the grower nets \$66 and we get \$33. The problem with specialty crops is that few traits are available that will pay back the investment. In potato, there aren't many \$300 or \$400 traits, and a \$100 trait won't pay the bills.

Traditionally, with row crops, new varieties were produced by plant breeders—mainly at the universities—which seed companies multiplied and sold (Figure 12). Farmers planted them, and the produce became widely available. In the biotech industry as soon as a stable transformation is achieved, breeding is initiated to put the trait into appropriate germplasm; accordingly, genetic manipulation, breeding and seed dissemination are now united in one entity, usually achieved through acquisitions. Like the traditional way, the biotech product then goes to the farmer, and then it goes worldwide.

With potatoes—and probably a few other crops—the farmer, the food processor and the food processor's customers are vertically integrated (Figure 13). Accordingly, 95% of the potatoes that are planted for the French fry industry are contracted by the food

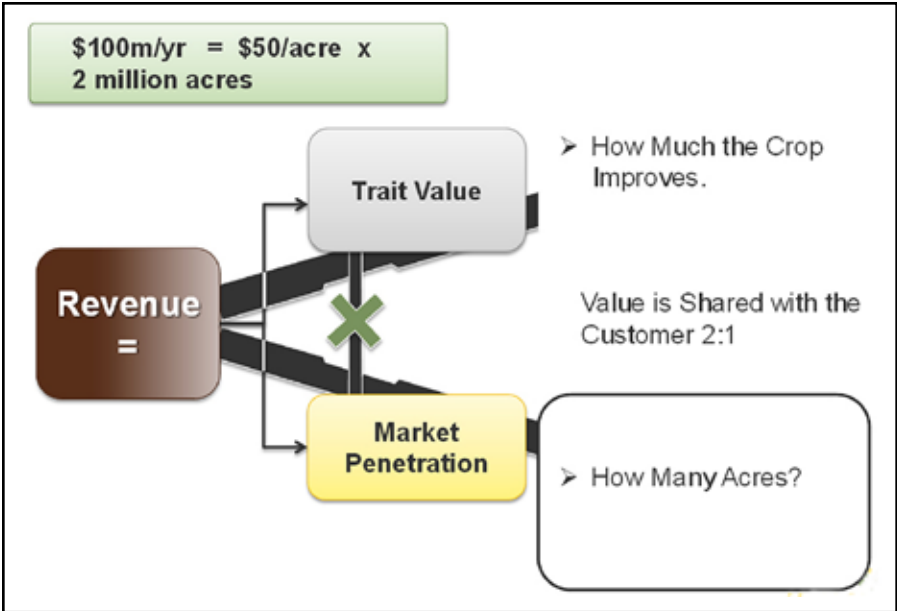


Figure 11. Revenue model for the biotech industry.

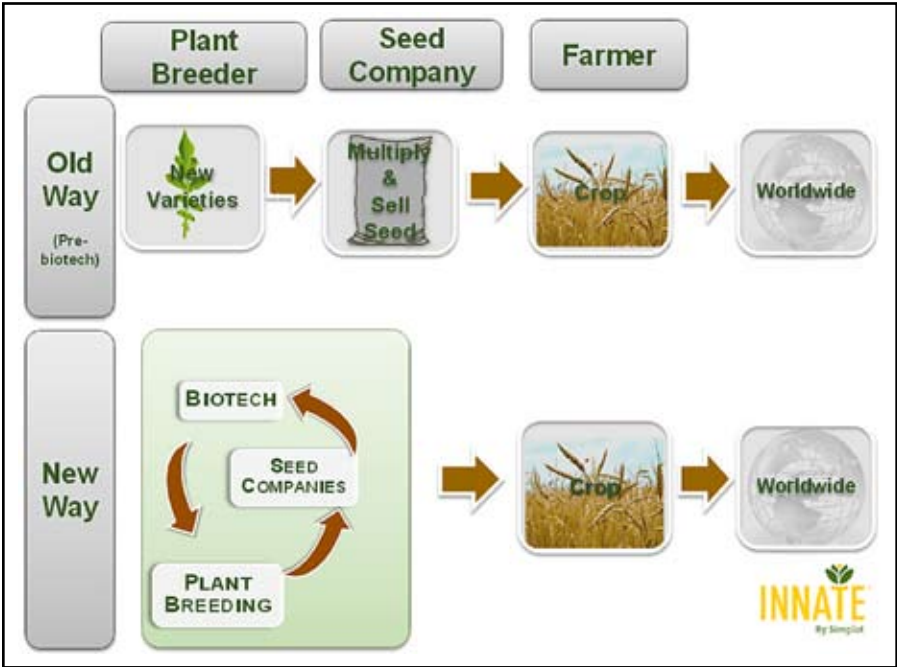


Figure 12. Crop development.

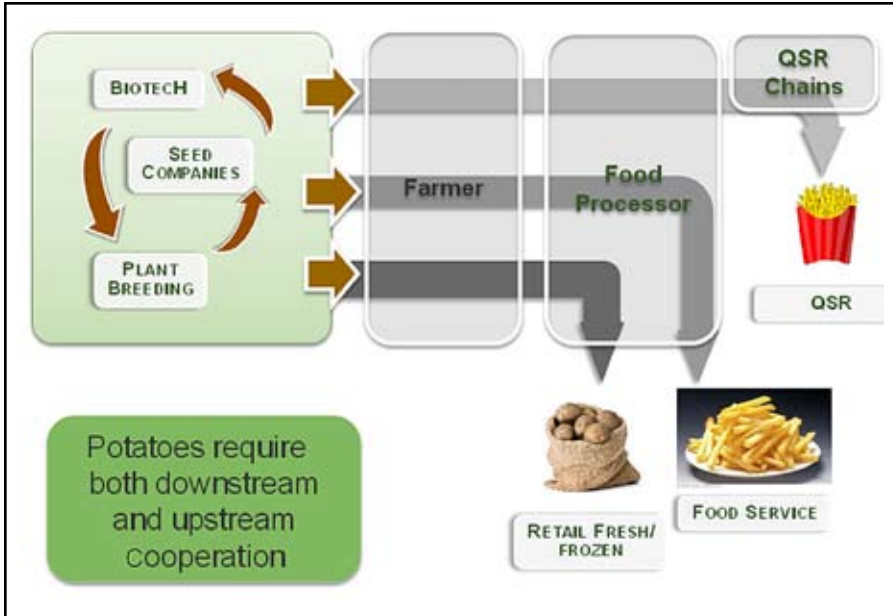


Figure 13. Potato commercialization.

processor. The food processor tells the farmer which variety to buy, and, if the quick-service restaurant (QSR) chain is large enough, it tells the food processor which variety to make French fries with.

These three entities operate in unison, so if a new variety is to be introduced, all three have to be lined up, or markets must be found where at least the food processor and the farmer can line up. Fresh and frozen present those opportunities. And food service is another. Customers sometimes aren't picky, so achieving that alignment may be harder than it sounds.

FINAL THOUGHTS

We have found the number of traits that are gene-silencing based, which should mean a less complicated regulatory package. In terms of reducing expense, not introducing a new protein is a significant advantage.

Another thing we have found is that the traits aren't always obvious. It took us a couple of years to fully understand the benefits of the low-sugar trait and its economic implications. It was necessary to store potatoes for 6 months and then make fries or chips.

A tricky point: the black-spot bruise trait benefits growers, and that benefits processors, which benefits the consumer. It's win-win-win. But it presents a challenge in terms of who pays. Presumably it's the farmer, who must get some of that money from the processor, who then must restructure the contracts with reluctant farmers. Calculating value thus becomes problematic.

Lastly, it can take a while to structure relationships and get people comfortable with biotech. On the other hand, after they're comfortable, we've seen significant support. We're in a comment period now, and 80 comments have been received, of which probably 25 are positive, a lot of them from growers. We are excited about that.



HAVEN BAKER is the vice president of new market initiatives at the JR Simplot Company, a \$4.5 billion private corporation with fertilizer, food and livestock divisions. At Simplot, he works on identifying and commercializing new technologies and opportunities across the agricultural space. He is the general manager of Simplot's plant-sciences business.

Dr. Baker has significant experience in the biotechnology industry, including working with several start-ups and managing a proteomics research lab at the Barnett Institute in Boston. Prior to joining Simplot, he also worked as an investment professional at Clarium, a global-macro hedge-fund company in New York.

Baker has a BS from Yale, a PhD in chemistry from Northeastern University, and an MBA from Harvard Business School. At Harvard, he worked with Clayton Christianson on concepts developed for the Social Innovation Fund.