Who Pays for Tree Improvement?

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Abstract: Tree improvement has been one of the most successful collaborative research efforts in history, eliciting participation from a wide variety of players. This effort has included state forestry agencies, research universities, integrated forest industries, and the USDA Forest Service. Tree improvement was organized through cooperatives whose objectives were to distribute responsibilities, rights, and rewards fairly and equally. Mergers, which accelerated in the 1990s, followed by land divestitures from integrated forest industries to institutional investors, and the rise of nursery businesses marketing genetics directly to landowners, have resulted in a much more heterogeneous business environment. With increasing disparity in organizational capabilities, changing economic goals, and the increasing costs along with potential benefits of biological research, it is unclear as to whether collaborative tree improvement efforts will remain viable. Game theory offers an explanation as to why tree improvement collaborations have been successful in the past, points out shortcomings in the current cooperative structure, and offers some insights into how we may choose to manage our future.

Keywords: tree improvement, silvicultural cooperatives, game theory, collaborative research

Introduction

Tree improvement programs, since their inception more than 50 years ago, have been collaborative efforts between state forestry agencies, research universities, and large, integrated forest industries. The USDA Forest Service has led the effort in some regions and has supported basic research in forest genetics in all parts of the country. Tree improvement programs have been responsible for much of the gain experienced in forest productivity, either directly by providing better planting material or indirectly by serving as a model for many other silviculture cooperatives (Todd 1995; McKeand and others 2006; see also Vance and others 2010). Key to this success was a model of distributed ownership where responsibilities for selecting, preserving, and breeding plant material were shared among participants. This made it possible to evaluate the large numbers of individuals needed to make rapid initial gains despite the fact that trees are large, long-lived organisms that require many large plantings to adequately evaluate performance.

One of the drivers behind this success has been the belief that “a rising tide raises all boats.” Increasing forest productivity was seen as desirable public policy supported by the state forestry agencies because it benefited the family forest owners directly and contributed to overall economic activity. Integrated forest industries benefited from increased forest productivity through development of a stable and inexpensive source of raw material. Under these conditions, it made sense to keep the cost of seedlings low. This was done primarily by pricing seedlings on a cost-plus basis accounting for the expenses of orchard management and nursery production. The value added by tree improvement was largely ignored and the cost of genetics programs was subsidized from other sources. Financial support was primarily from publicly appropriated funds and corporate research budgets that could be partially written off corporation taxes (Figure 1). In other words, tree improvement was supported by a number of organizations with more or less similar goals, capabilities, and motivations. Historic investments in tree improvement and the current structure of tree improvement cooperatives reflect these equities and also encapsulate the elements that will cause future organizational strains (Byram and others 2005).

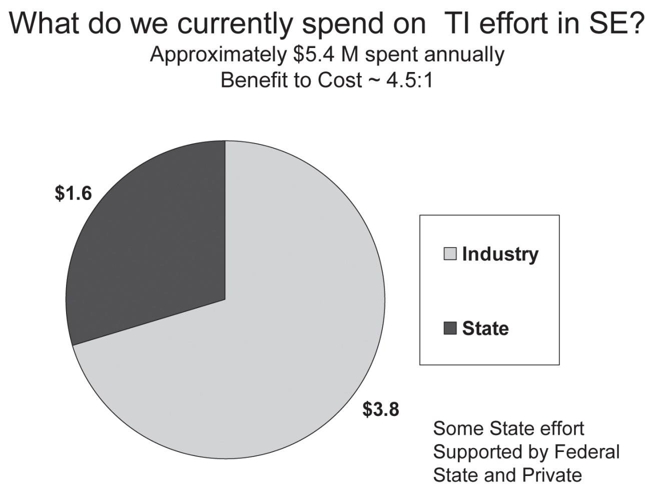

Figure 1. In-kind support for southern pine tree improvement (in millions of US dollars) from a 2007 survey of the members of the North Carolina State University Cooperative Tree Improvement Program, the Cooperative Forest Genetics Research Program, University of Florida and the Western Gulf Forest Tree Improvement Program (McKeand and others 2007).

What Prevents Us from Using the Same Highly Successful Model Going Forward?

The ugly truth is that while making the best genetics widely available may make good public policy, it also makes genetics a low-value commodity from which it is difficult to make a direct profit. This situation is not unique to forest trees but is a problem shared by all minor crops, many that have breeding programs supported primarily by the public (Berland and Lewontin 1986). This constraint has actually been less problematic in forest industry than in other breeding programs for at least two reasons. First, the cost of tree improvement, including in-kind contributions, has been relatively modest given the value of the crop. Second, and more importantly, most participants in forest genetics programs made their profits with their manufacturing facilities, not from the sale of genetic improvement, where most seed companies make their incomes.

Mergers among integrated forest companies, that rapidly accelerated during the 1990s, were followed closely by the divestment of corporate forest land to institutional investors. This resulted in a reduction in the number of players that could logically participate in breeding programs; these programs benefit from the economies of scale. Concurrently, several state agencies adopted the position that economic development should be left to the private sector, and have closed tree improvement programs, abandoned orchards, and shuttered nurseries. Furthermore, the new class of large institutional forestland investor/owners frequently has different investment criteria than those historically held by integrated forest industry. Some have recognized that they have a vested interest in forest productivity to reduce the cost of their own production and to maintain a viable manufacturing customer base. These organizations have been both aggressive and innovative in maintaining their commitment to tree improvement programs. Other institutional owners, representing a sizeable proportion of the landbase previously supporting tree improvement programs, have opted to buy seedlings on the open market and essentially forego the in-kind cost of tree improvement. This is a completely rational decision where fragmented ownership reduces the size of holdings within any one breeding and deployment zone below the level needed to support a stand-alone tree improvement program.

Concurrent to the withdrawal of state forestry agencies from seedling production and the rise of a new base of customers, a stand-alone forest tree nursery business has arisen. This was made possible, in part, by the divestiture of land by forest industry. As some organizations no longer had an internal need for seeds, the consequence was that the best genetics from existing orchards have become more widely available. These new ventures market a wider range of genetics than previously available, but must make their profit on the sale of seedlings rather than higher value stumpage. Strategies for a nursery business can include selling a low cost commodity where there is little incentive to develop new products. Alternatively, market differentiation can be developed by selling full-sib families, varietal lines, or seedlings that differ genetically from other sources on the market. These seedlings offer good genetic value to the customer. Unless the market recognizes their economic value, there will be little incentive to invest in the future of tree improvement. Market differentiation can also drive increased competition. As tree improvement is primarily a pre-commercial population development program, this need not limit collaboration and, in fact, sharing the cost of development could be an incentive for more intensive cooperation.

Tree improvement is now poised to make remarkable gains. Swift progress is occurring in vegetative propagation, selection efficiencies, and deployment strategies. Substantial investments are occurring in silviculture research (Vance and others 2010) and basic genetics (Whetten and Kellison 2010) that can make our forest potentially far more productive. The USDA National Institute of Food and Agriculture (NIFA) is making very large investments in basic research and proof-of-concept type experiments (NIFA 2010a, 2010b); the results from this government- sponsored research, however, will have to be translated into operational programs through applied breeding programs. As a consequence, future tree improvement programs will require community resources far beyond what has been considered normal in the past (Table 1). In addition, it is likely that it will be desirable to measure attributes such as BTU content or nanostructure reactivity that will involve investments in new equipment or the development of service laboratories (Briggs 2010; Wegner and others 2010). These factors offer tremendous opportunities to improve productivity and to develop novel products, but they will come at an increased cost and complexity that we have not yet incorporated into our current system.

Table 1. Infrastructure that may be needed to support a modern tree breeding program.

Germplasm Conservation Scion banks and long-term seed storage	
DNA Stock Centers	
	cDNA libraries
	BAC libraries
	PCR primer sets
Research Populations	
	Association and mapping populations beyond standard progeny testing (crossing, establishing, maintaining, and measurements)
Specialized Skills in Biometrics	
Laboratory Facilities for Phenotyping	
	Wood density
	Microfibril angle
	BTU content
	Fermentation /conversion efficiency
	Nanocrystals
	Nanostructure reactivity

Complexity comes in many forms, but probably the most challenging to the current structure will be the need to manage intellectual property. In theory, this can be done by assigning responsibilities, rights, and rewards according to each organization's contribution. Tree improvement programs have been extremely successful over the past 50 years, working with handshake agreements as these three factors have been more or less equally shared. It seems unlikely that this structure will be successful going forward as organizational capacities and goals diverge.

What Can Game Theory Teach Us about Tree Improvement?

These substantial organizational difficulties can be overcome. Game Theory, the study of how individuals interact and organize (see for example Myerson 1991), offers an explanation as to why tree improvement collaborations have been successful in the past, points out shortcomings in the current cooperative structure, and offers some insights into how we may choose to manage our future. Briefly, collaborations develop when the benefits to the participants exceed what they can expect from acting as individuals. In other words, individuals will work together when the whole is greater than the sum of the parts. This has certainly been true in tree improvement programs where population development is primarily a pre-commercial development program that benefits directly from economies of scale. In Game Theory terminology, shortly after collaboration develops, "cheaters and freeloaders" emerge that reap the benefits of the collaboration without contributing to the group. The system conveys a competitive advantage to them, so their decision is completely justified from an individual's perspective. Their emergence within the system is inevitable and unavoidable.

Collaborations can tolerate some level of defection, which again reflects conditions in tree improvement's past. For example, nurseries operated by integrated forest industries could afford to subsidize seedlings for outside sales because this reduced the per-unit cost of seedlings used internally. When the motivation to "cheat or freeload" reaches a critical level, however, one of two things will happen. Collaborations collapse and a competitive environment predominates, or methods are found to promote continued teamwork through incentives and/or punishments applied to limit defectors. An important corollary is that collaboration is not always the best option. When development of a product is anticipated to be costly and economically risky, the prospect of having a competitive advantage is frequently a necessary motivation for making the required investment. Examples from our industry include the development of varietal lines and genetically modified trees. A second corollary is that enforcement of collaboration in the face of increasing pressures to defect comes at a cost to the partnering organizations. This is frequently in the form of increased complexity, lack of individual flexibility, or increased operating expenses.

Therefore, according to Game Theory, three conditions must be met for continued collaborative tree improvement efforts to be warranted: 1) net benefits of collaboration must exceed those of competition; 2) benefits must also exceed the cost of enforcement against defectors; and 3) participants must perceive that responsibilities, rights, and rewards are fairly distributed. Condition 1 will be true as long as population improvement is deemed a priority because very large breeding programs are out of reach of single organizations. In fact, the opportunity cost in allowing collaboration to atrophy would be substantial if the comparison to corn yields is accurate (Figure 2). Conditions 2 and 3 can be met with appropriate organizational structure that fairly distributes costs and manages intellectual property. If done properly, this would encourage investment from landowners and investors with a vested interest in improved forest productivity that currently opt out of directly supporting tree improvement research.

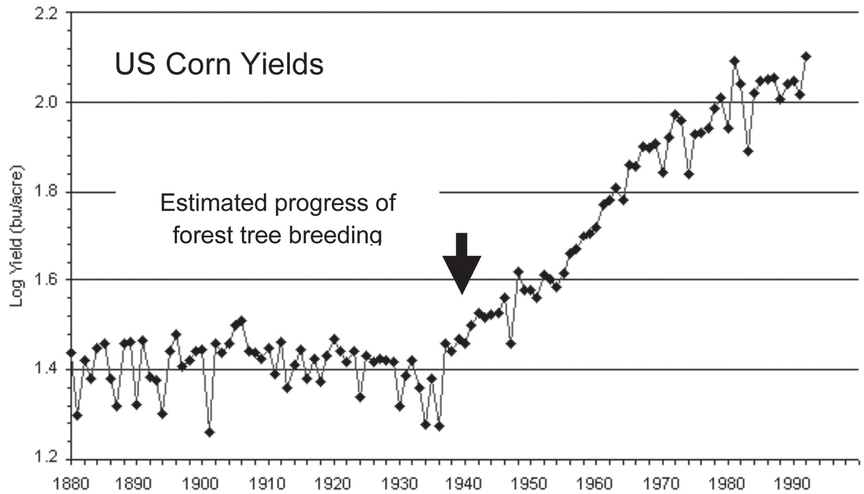

Figure 2. Estimated progress of forest tree breeding from realized gain and number of generations in the breeding program compared to the actual US corn yields reflecting the application of modern breeding programs (corn yields from Ruttan 1999).

Other crops have done this by collecting a mandatory check-off fee at the point of sale that is then used to support research (for example, the Cotton Board and the National Peanut Board). This system supports university research that supplies breeding stock to seed companies who in turn sell seeds to farmers. An analogous system in forestry would be the collection of a check-off fee at the mill gate based on delivered tonnage. The cost of tree improvement would then be paid by the landowner and/or manufacturer who arguably benefit most directly from investments in productivity improvement. This solution, however, is extremely unlikely for forestry as it would require legislation.

Conclusions

Forestry could follow another structure made possible because our production model is somewhat different. We are simultaneously the research arm, the seed company, and in many cases, also the farmer. A breeders association could raise funds based on a voluntary metric, such as the amount of outside seedling sales, and redistribute this income to support breeding and progeny testing and the necessary community resources listed in Table 1. Regardless of the model the forestry community ultimately chooses, we believe it should incorporate the following elements:

1. Those that benefit from tree improvement should pay for it. While the ultimate beneficiary is the consumer and the society to which he/she belongs, this is too nebulous to be practical. The points in the value chain where money changes hands determine the logical places where value can be captured. Possible links in the value chain are: 1) sale of seeds; 2) sale of seedlings; 3) sale of stumpage; 4) sale of a manufactured product; or 5) taxes raised due to increased economic activity.
2. Additional funds over and above the in-kind support currently provided by the participants in tree improvement cooperatives (Figure 1) must be generated so that the infrastructure and community resources necessary to support a modern tree improvement program can be funded. The implication of the need for additional sources of funding is that participation of defectors will have to be enforced.
3. An infrastructure should be created so that money raised goes to those who add value. Since this must be viewed as fair by the participants, a pay-for-performance system seems appropriate. The organizations that add value are those that create intellectual property in the form of ever better genetics, that is, those that do the actual breeding and progeny testing. We propose that the Cooperative staffs hosted at the universities should continue to raise their funds as they do now, by selling services to support the breeding and testing organizations.
4. Intellectual property developed through collaborative breeding programs must be actively managed to parse responsibilities, rights, and rewards fairly. This is necessary to encourage and value participation by organizations of vastly different capabilities by according them the rights and rewards that are consistent with their contribution. Simultaneously, cooperative breeding populations need to be available to proprietary breeding programs in a system that encourages and rewards innovative product development.

Historically, tree improvement has been one of the best investments a landowner could make. We have certainly only begun the process of crop domestication in three generations of breeding and stand to make even faster and more valuable progress in the future due to rapid improvements in the biological sciences. Whether these aspirations are realized will depend largely on the organizational choices we make. Our future is up to us.

Acknowledgments

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