Summit Proceedings

Seeds and Breeds for 21st Century Agriculture

Edited by Michael Sligh and Laura Lauffer

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- Strengthen family farms and rural communities
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- Ensure responsible use of new technologies

The Summit on Seeds and Breeds for 21st Century Agriculture provides an open forum for the discussion of issues related to public plant and animal breeding. The views presented and positions taken by individual participants and presenters are their own and do not necessarily reflect the views of RAFI-USA.

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- Inspecting Nokomis Gold corn in northern Iowa. Photo by Walter Goldstein, Michael Fields Agricultural Institute, East Troy, Wisconsin.
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Preface

- **Summit on Seeds and Breeds for 21st Century Agriculture**
  Washington DC - September 6-8, 2003

Background

At the beginning of a new century, as we face many complex societal and environmental problems, it is important to reassess how plant and animal breeding coupled with genetic conservation might best contribute to the development and maintenance of a healthy agriculture. Agriculture in our country involves a vast array of crops produced in a wide range of climatic, economic, and cultural environments on widely diverse farms. New market opportunities for value-added products such as organically grown foods are increasing. It is in our interest to ensure a broad availability of crop varieties and animal breeds to enable farmer and consumer choice. We need plant and animal breeding programs that will enhance biodiversity, assure free flow of knowledge, reflect societal goals and farmer's needs, balance the public-private breeding relationship, and maintain and enhance technical breeding competency.

Furthermore, breeding programs could truly serve the public interest if they were targeted to support farming systems that enhance or maintain the quality of our soil, water, and air resources while producing adequate quantities of high-quality, nutritious agricultural products. Such sustainable systems are often multifunctional; they also integrate animal production and organic wastes while optimizing nutrient cycling and other soil conserving practices. They also include animal production systems, which are designed to maintain animal health and well-being and thereby reduce the need for antibiotics.

Current developments towards a more locally based, more diversified, and more sustainable agriculture present new needs, challenges, and opportunities for public breeding programs. New breeds and crops are needed to enhance the function and long-term success of such farming practices, and to fill the demand for products with demonstrably enhanced nutritional or culinary value. Innovative linkages must develop among researchers, farmers, and seed or breeding companies to assure that a new set of goals and methods is taken up to meet the needs of this new, developing agriculture.

Regrettably, the United States has not taken a long-term, comprehensive, strategic approach to these challenges and public sector breeding has declined. Currently, the USDA's Agricultural Research Service (ARS) and land grant universities (LGUs), once major developers of new varieties and breeds, release relatively few new varieties or breeds as compared with the private sector. In addition, the development of new tools of biotechnology and the ability to protect both genes and methods for genetic modification as intellectual property have further attracted private-sector investments in the development of seeds and animal breeds for farmers relative to the public sector.

So, in this era where control of elite germplasm has increasingly become proprietary, it is important to strike a new balance through reinvigorated and enhanced activities and investments within the public domain. Public programs are best suited for the higher risk efforts of developing new crops and breeds to meet public needs. Such needs include the need for a diverse array of nutritious products that are readily accepted by consumers and farmers, to meet the needs of new markets, and to address the growing environmental, health and societal challenges of the 21st Century.

However, there are formidable barriers to focusing public breeding to serve this vision of public interest. Breeding programs are long term in their nature and they will need long-term support. Current academic structure and reward systems may limit the numbers of scientists willing to participate in long-term breeding projects, even though these projects may be in the public interest. Furthermore, programs that will address the needs and goals of farmers and the public may need to have new participatory and multidisciplinary structures.

Goals

This Summit on Seeds and Breeds for 21st Century brought together a selected group of scientists and participants from concerned organizations and government to address these needs and limitations and the potential for reforming public breeding and funding policy.

Our specific goals are to use this summit to:

- Develop a blueprint or road map for re-invigorating public domain plant and animal breeding to meet the needs of a more sustainable agriculture.
- Build momentum to continue to work together toward common goals.
- Launch a campaign to educate policy makers.
- Publish sound actions for achievements and progress toward these goals.

Michael Sligh, RAFI-USA

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Opening Papers

An International Perspective on Trends and Needs in Public Agricultural Research

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Introduction

Malthus got it "wrong" in the 1700s, not because there is no linkage between the number of people to be fed and the productivity level of an agricultural system, but because he just could not imagine a sufficiently dramatic increase in agricultural productivity taking place in 18th or 19th century England. Indeed, one was already underway as he was writing. His equation would have had deadly accuracy if only his assumptions were correct. But, one of his assumptions – that the rate of increase in agricultural productivity is and *must be* slower than that of population growth – was incorrect, at least to date, at least in his England. Where did that productivity – invisible to Malthus – come from?

- Increases in land devoted to agriculture
- "Modernization" including new varieties, fertilizers, and mechanization
- Policies: including "enclosure"

Is there any cause today to be concerned with agriculture's ability to feed a still growing population? Are the circumstances today, in the 21st century, still fundamentally the same as in Malthus's time? On the surface, it would appear that the screw has tightened. In the 18th century, population increased at the rate of 250 million every 75 years. In contrast, such an increase only takes 3 years now (Evans, 1998). Is production not part of the people/food equation? Of course it is, particularly at the local (i.e., consumer) level. Particularly, when you consider that the "need" for production/consumption will not (as in Malthus's) time be experienced where the technology and resources are most abundant, but where they are least abundant. Eighteenth and nineteenth century England had certain advantages in addressing the food needs of a rapidly growing population that Africa does not have today. Fifty years ago, Africa had half the population of Europe. Twenty years from now it will be three times bigger. The scale of Africa's challenge is orders of magnitude greater than that of England which, fortunately and conveniently, "proved" Malthus wrong.

There are only a limited number of ways in which production can be increased. Evans (1998) lists six ways:

- Increase the area of land under cultivation.
- Increase the yield per area of crop.
- Increase the number (plantings) of crops per area, per year.
- Displace lower yielding with higher yielding crops.
- Reduce post-harvest losses.
- Reduce the use of feed for animals (use less animal protein).

The most successful method historically (increasing the acreage under production) is rapidly becoming a non-option. But, in order to feed 10 billion (by approximately 2050), we will have to raise global grain yields to a level higher than current averages in Europe and North America - unless we do the seemingly impossible and increase acreage under cultivation dramatically.

All of the other (non-acreage increasing) options are either technically difficult, marginal in effect, or politically unpopular. Ask yourself: which of all the options for increasing production do I support? More than a few agricultural policy "experts" support none, but call rather for the far-from-imminent solution of redistribution, which has thus far in history failed to garner enough support even to generate a serious discussion about the practical problems associated with redistribution. And, to be honest, large-scale redistribution of grain from North America to Africa and South Asia will still require enormous increases in agricultural productivity in North America if global food needs are to be met in 2050. So, there is no escape from the question of production, and indirectly from the question of how we figure out how to increase it some day. Intensification – sustainable intensification – is the name of the game. (This, I hasten to add for fear of being misinterpreted, does not mean that production can or should be increased without regard to environmental or human factors. Productivity gains must be achieved in a manner contributes positively to food security.)

All non-acreage increasing options – popular, unpopular, significant in effect, marginal – will require agricultural research…public agricultural research. We could ask ourselves: "what's in the pipeline?" But, rather than do that, let us ask: "what's the state of the pipeline?"

Data on funding for international agricultural research shows an increase (in constant dollars) up until the early 1990s (Pardey and Bientema, 2001). This data masks three important problems:

1. There are huge disparities in expenditures, with low-income countries spending a fraction of the amount, per capita, that high-income countries spend. Moreover, a few developing countries account for much of the expenditures of all developing countries.

- Forty-four percent of the developing world's agricultural research expenditure is accounted for by just three countries: China, India and Brazil.
- In 1995, Brazil spent $900 million on agricultural research. Most countries in Africa spend less than $20 million. Only two spend more than $100 million per annum.
- If one looks at "intensity," a measure of how much research is done relative to production, research in rich countries is eight times more intense.
- Rich countries spend 69 times more than poor ones per agricultural worker.

2. The increase was not evenly spread. The amount spent in Africa has actually declined the past 20 years (Pardey and Bientema, 2001).

3. The data typically cited stops just short of the point in time when countries began cutting agricultural research budgets and as donor countries moved to exert more control over the content of the research.

- Significant decreases in the late 1990s in the Consultative Group on International Agricultural Research (CGIAR) budget occurred simultaneously with a large increase in the percentage of this budget that was restricted or "tied."
- Aid funding of agricultural research declined by 75% from the mid-80s to 1996. Asia has suffered the most, but all regions have been hit.

Those who would casually suggest that developing countries could or should build up their agricultural research structures along the same lines as systems in developed countries are naïve to the enormous challenges involved, including the relative lack of trained scientists (as compared with the situation in developed countries). Assessing the situation, Pardey and Beintema (2001) note "…the immensity, if not the outright impossibility, of playing catch-up, and the consequent need to transmit knowledge across borders and continents."

How, then, do we create a vibrant public sector that serves society's needs, particularly the needs of developing countries?

First, what are those needs? Three principal ones can be quickly identified:

- Research, particularly that which is not otherwise undertaken by others (including new methodologies and technologies as well as work on crops of local importance that are not being adequately developed at the present time).

- Ensuring that core technologies and resources (genetic, etc.) are in the public domain, conserved and available for use, in order to encourage and make possible future research, development and deployment.
- Education of the next generation of researchers.

The issue is not just money. Perhaps as importantly, it is about the management of agricultural research. And, of course, it is also about a division of labor. A few words about each:

Money:

I have already noted stagnating/declining budgets for agricultural research. Internationally, the decline has been greater than the figures indicate, because much of the budget – particularly in developing countries – goes to provide salaries to office workers and others that are far removed from actual research. For example, I have personally seen the inner courtyard of one country's major research institution fully ringed by the dilapidated and rusting hulks of vehicles (long since deceased) donated by aid agencies. The researchers had no way to get to their own fields. I also know of quite a few situations where national research programs are unable to test (much less research or adapt) new crop breeding lines produced by the CGIAR. Why? Simply because they do not have the money to plant the seeds being given to them. Here we are talking about operating budgets of zero.

The 16 Centers of the CGIAR are, modesty aside, the jewels of international agricultural research. With less than 3% of the total budget for global agricultural research, their contribution is tremendous.

Comparing finances, the Michigan State University Agricultural Experiment Station has a budget that is roughly twice that of the largest of the CGIAR Centers. The International Maize and Wheat Improvement Center (CIMMYT), with an annual budget of less than $40 million, works on two of the three most important food crops in the world and their associated natural resource and economic problems. The Michigan State facility serves primarily a state clientele of 8,000 full-time farmers, 16,000 part-time farmers, and 27,000 "hobby farmers" (Eicher, 1999). By comparison, 85 percent of all spring bread wheat varieties and 86 percent of all spring durum varieties released in developing countries from 1966 to 1997 were based on CIMMYT materials (Heisey et. al., 1999). CIMMYT's maize breeders, meanwhile, released hundreds of new lines and recently won the prestigious World Food Prize for Quality-Protein Maize. With half the resources of the state of Michigan, CIMMYT serves a clientele that literally numbers in the billions in terms of consumers and hundreds of millions in terms of farmers.

Similarly, the entire CGIAR system with its 16 Centers and dozens of outposts and facilities is only the size of the Brazilian national research program in terms of budget and professional staffing. It cannot be surprising that the CGIAR Centers have not "worked their way out of a job" by building up capacity in the national programs, which some cite as a failure of the CGIAR, in large part because it was a hope and dream of the CGIAR's founders. No amount of capacity building or back-stopping on the part of the CGIAR will ever be sufficient if national governments continue to pull the plug on their own research systems. CGIAR Centers can and should do more, but so too should key aid donors and the developing countries themselves.

Most countries – even many of the poorest - spend enough on agricultural research to be able to afford to have a CIMMYT of their very own. Few, if any, do no matter how much they spend. Questionable priorities combined with the deceptiveness of the budget data (as noted above) mean that less is being accomplished than one might imagine – and far less than is possible.

The World Bank, in part because of a substantial absolute and relative decline in its agricultural lending portfolio, has recently announced a new focus on education and training. Agriculture is slipping away gradually but surely. Similarly, the U.S. Agency for International Development (USAID) has focused very little on agriculture during recent years, although the new Administrator has promised to reverse this decline and appears to be doing so. This is the silver lining in an otherwise bleak picture internationally.

Two other brief comparisons of finances:

- In 1998, the CGIAR spent $25 million on biotech research; Monsanto spent $1.26 billion.

- The Salt Lake City Olympics cost $342 million according to the GAO….or $1.5 billion according to Sports Illustrated!

The first comparison provides some sense of the scale of difference between public and private sectors, and of how little of the total financial resources of society the public sector is actually drawing down. The second comparison says something about social priorities. Comparisons, however, are easy, frustrating and ultimately unproductive. They reveal life's ironies and absurdities, but they do not point to realistic solutions. Olympic funding simply is not available for agriculture. We know that more funds are needed for agricultural research. But, much progress could be made by better managing existing research and funding and we must acknowledge this and be willing to hold ourselves and others accountable.

Management:

Much of agricultural research in/for developing countries is donor-financed. Everyone wants more money, but I can tell you that within the CGIAR, researchers would be happy simply to regain control over their own research agendas and budgets. For several years I had the honor of being a member of the Board of Trustees and serving as the chair of Board's program/research committee for the largest of the CGIAR Centers (CIMMYT). Given the opportunity, the one thing I would change about the management of research at CIMMYT and within the CGIAR would be to return to the good ole days when funding was not tied by donors to specific (often donor dreamed up) research. In the early 1990s, 14% of funding to the CGIAR was tied. Today, it approaches 50%. Having half of your funding restricted does *not*, by the way, give you the freedom to run half your research program according to your own tastes. The half you get to use freely has to pay for the overhead of the institute: electricity, water, machinery, administration, etc. Thus, donors that provide unrestricted funding end up subsidizing those who micro-manage from an office building on another continent. The very Centers that produced such huge results without the micro-guidance of donors are now in danger of becoming contractors for aid agencies – agencies with far less on-the-ground presence, or knowledge, or accountability, than the Centers and scientists themselves. Centers do not wish to bite the hand that feeds them, but all grumble bitterly about the current state of affairs.

Donors' preferences change yearly, if not more frequently. Try running a long-term research project based on annual budgets and donor whims. Most administrators do, of course, but they typically have a base or core budget that serves as a foundation, backed up by the taxing authority of the government. International Centers are not so lucky. Everything is up for grabs. Yearly. Up for grabs with every change of government, indeed with every change of mid-level personnel and desk officers in the funding agencies. Perhaps the picture is not quite this bleak, but I will argue that cutting edge research, long-term research, and all research that is inherently difficult for mid-level administrators to understand, has suffered. Plant breeding – the great area of comparative advantage for international centers and the best example of returns on investment in agricultural research (no evidence of diminishing returns!) – has declined in recent years in the CGIAR. Why? Because the need has lessened? Because demand from developing country programs has declined? Not at all – the need and demand has increased. Donor interest has lessened. And, Centers are, in effect, being pressed to reduce breeding further to support areas that are more "sexy," more politically correct. How these new areas correlate with needs, how they measure up in terms of contributions to food security or even return on investment might be questioned, but they are popular and so they expand.

Division of Labor:

The debate about how the public and private sectors should divide the work-load is more than 100 years old (Fowler 1994). In its simplest form, crops or even geographical regions get assigned to one or the other. The private sector gets maize and North America, the public sector gets cassava and Africa. As we know, reality is a bit more complex.

Let us look at three crops: bananas, yams and lathyrus.

Bananas are the world's most popular fruit. They are also the staple food for hundreds of millions of people. Annual production is approximately 70 million metric tons. They are grown on about 11 million acres (FAOSTAT, 2003). In Uganda where the word for bananas, "matooke," is also the word for "food," 450 kg per person is produced annually (INIBAP, 2003).

Most cultivated bananas are seedless and sterile and thus difficult and time-consuming to breed. Fungal diseases are a major problem. Commercial plantings are protected by as many as 40 sprayings a year. Recent press reports have voiced concern about the continued viability of the crop due to disease outbreaks.

The real threat, however, has to do with the level of public investment in this, one of the world's most important crops. According to the International Network for the Improvement of Banana and Plantain, there are only *five* scientists, globally, breeding bananas.

By any definition, yams are a major crop. In 2002, 38 million metric tons were produced in Africa, which is the largest producer. They were grown on 10.4 million acres (FAOSTAT, 2003). Ask the average person how many yam breeders there are working on such a crop and you may get guesses such as 50, 100, 200, etc. I have done this. I know. The answer – or informed guess - according to my contacts in the CGIAR, is *three*. Two at the International Institute for Tropical Agriculture (IITA), a CGIAR Center headquartered in Nigeria, and one in the national program of one African country. The private sector is not particularly interested. Here is a major crop orphaned by both private and public sectors. Should the public sector focus on minor crops and leave major crops to the private sector? Not if the crop is yams. Sadly, many other major crops are similarly neglected by everyone.

Lathyrus (*Lathyrus sativa*) is a different kind of crop. A legume with pretty little purple flowers, it is extremely drought-tolerant. It will survive when little else does, and thus has become a "famine" food in Bangladesh, India and Ethiopia, in particular. But there is a problem: it contains a neurotoxin that becomes especially concentrated precisely under drought conditions. Eat enough, and you will become paralyzed from the knees down. Permanently. For the poorest of the poor, the choice can become a tragic one: starve or become paralyzed. Thousands in a normal year "choose" paralysis. Clearly, Lathyrus is a "public sector crop." There is a public sector program – at the CGIAR's International Center for Research in the Semi-Arid Tropics (ICRISAT) - aimed at breeding varieties with low levels of the neurotoxin. Imagine the support it gets.

It should be noted that many private sector breeding programs in crops such as corn, sorghum, soybean, etc., are recipients and beneficiaries of genetic materials developed by the public sector. It is also important to realize that at least some of the capacity of the private sector to serve a country's needs is actually provided by the public sector through public-private partnerships formal and informal.

Plant breeding programs are a form of social insurance. In good times, plant breeders toil away and typically help raise the productivity levels of a particular crop through the introduction of new varieties. In times of crisis, when new diseases appear or old ones evolve and "explode" with virulent outbreaks, plant breeders are called upon to rescue crops, industries and people. If this form of insurance is to work, a certain amount of capacity must exist at all times. Plant breeding programs cannot be instituted over night. There is no Red Cross of plant breeders able to fly in and take care of emergencies. One cannot take a pea breeder today and ask him/her to switch crops and tackle a banana or yam problem tomorrow. The breeder must understand the crop and the agricultural systems it is found in, know the crop's genepool, assemble genetic resources, and begin breeding. No one in their right mind would establish a multi-billion dollar industry on whose success hundreds of millions of people's lives depended and then fail to pay the insurance bill on the facility. Yet, with only five banana breeders and three yam breeders and even fewer devoted to lathyrus, this is what we are doing crop by crop.

The situation is at its worst with vegetatively-propagated crops such as bananas and yams, but the amount of resources and breeders devoted to other crops is frequently just as low as it is for these. Few if any crops are adequately addressed by the public sector, or the private sector, or the combination.

Several points can be made: superficial divisions of labor make no sense and do not exist in the real world. This is not "us" (public) against "them" (private). Neither is it a zero-sum game. It is about how to get the job done and how to use the scientific tools and resources we have to serve society. Concern arises when either the public or the private sector is weakened to the point that it cannot play its role or contribute in the ways it must to create a strong agricultural system and provide security against inevitable shocks and surprises. This is the situation we are now in, at least in terms of international public agricultural research.

Genetic Resources and the Public Sector

Public research depends on and advances the free flow of scientific information and, in the case of plant breeding, genetic materials. There can be little doubt that political, legal and commercial developments have undermined and diminished this flow in recent years (Fowler, et al., 2001). Ample attention has been given elsewhere to political and especially to legal (IPR-related) developments. A brief word about genetic resources is in order, however, because it is the indispensable raw material for plant breeding.

Countries are highly inter-dependent in terms of plant genetic resources for food and agriculture (Palacios, 1998). Norway, for example, depends on wheat genetic resources acquired over a long period from distant lands to sustain its wheat breeding programs and farming systems. While Norway certainly does not grow any citrus fruit or have any breeding projects in this area, it imports plenty of oranges and orange juice, plenty of sugar, maize, etc. The breeders and growers of these crops – wherever they may be located - similarly depend on "imported" genetic resources, and so does Norway, albeit indirectly.

Transfers of crop genetic resources have slowed considerably. While intellectual property rights have impeded the flow of certain types of resources (typically bred or improved materials), it has been the countries themselves that have closed and locked the door in most cases. Believing that they are sitting on genetic gold mines, some countries have restricted outside access to virtually everything they have, endangering both conservation and breeding efforts. Nationalizing the resource may play out well politically on the home front, but there is virtually no evidence that restricting the flow of genetic resources has brought any benefits to the countries that have taken such action (Fowler, 2002).

The recently adopted International Treaty on Plant Genetic Resources for Food and Agriculture promises to reverse the trend towards restrictiveness, but countries will have to implement it in good faith if a return to a culture of cooperation and generosity is to be achieved.

Genetic resource conservation is a quintessential public activity. Assembling and maintaining large collections of crop germplasm is beyond the capacity or interest of most private firms, and the work is so essential and of such a long-term nature that the public sector has rightly taken on the responsibility. Many nations now have genebanks, but few provide secure funding, and many are in a state of disrepair sufficient to prompt fears about the viability of the collections (FAO, 1998).

One recent development offers a ray of hope: the creation of the Global Conservation Trust. The Trust seeks to establish an endowment fund that will guarantee funding for the conservation of the world's unique crop genetic resources in perpetuity. Interest and income from the fund would be used to support genebanks holding genetic resources. The cost of establishing such an endowment – a one-time cost - is small, less than the price for putting on a single Olympics! And for this, the most valuable resource in the world – the one most essential to our own survival – will be safeguarded. This particular public sector activity should garner broad-based support from all segments of society.

Some Conclusions:

What can be said about the public sector, its importance, and its role in the future, especially at the "international" level?

The agricultural research budgets of most developing countries are stagnating/declining. Aid budgets are declining and agriculture's percentage of that declining budget is also declining – these are the budgets that underpin a considerable amount of agricultural research in developing countries.

Many research programs – especially in Africa, but also in Latin America – are below "critical mass" stage. While many such countries have production systems involving as many as a hundred crops, most have crop breeding programs engaged with only 2-4 crops, typically major crops where the country's scientific institutions have no particular advantage in undertaking fundamental research.

For many countries, the CGIAR *is* the national agricultural research program. Yet, CGIAR budgets have been in a state of decline for a decade, plant breeding has been reduced, staff has been laid off, and the ability to continue to recruit and retain new professions to financially insecure positions in such holiday locations as Colombia, Indonesia, Ivory Coast, Nigeria, and Sri Lanka (examples of locations of CGIAR Centers) is questionable.

Many, indeed most, developing countries do, in fact, spend enough money on agricultural research to be able to afford to have a CIMMYT, or an IITA, or an International Potato Center (CIP), which focuses on root and tuber crops. But few spend their money this way, and few have research programs that even remotely match those of the CGIAR Centers. This, as I noted earlier, is indicative of a set of internal problems that is not easily addressed from the outside. The only reasonably realistic response is to halt the decline in capacity within the CGIAR, and reverse this dangerous trend. Alternatively, or additionally, one could think of monetary and non-monetary incentives (through aid) that would encourage developing countries to reform and invest more in their own agricultural research. I am doubtful that this latter approach would be met with much enthusiasm in aid agencies around the world, so it will probably remain just a theoretical option.

Few would argue that if the public sector does not deal with minor crops, no one will. Internationally, many minor crops are major if considered by any of the following criteria: contribution to nutrition (including micro-nutrients), contribution to income (locally/regionally), contribution to food security and/or income at "low" points in the year, and importance in the cropping system. Clearly, the public sector should increase its involvement with "minor crops." Note that only one "major" international Center, The Asian Vegetable Research & Development Center (AVRDC) in Taiwan, works on vegetables for the developing world. (It has a budget of about $10-12 million per year.) Most vegetables (eg. African leafy vegetables) are not currently being bred/improved by a single full-time plant breeder! Imagine how much gain in productivity could be achieved if only Mendelian genetics were – for the *first time* in the 12,000 year history of agriculture – brought to bear on such species!

There is, and will continue to be, an important role for the public sector vis-à-vis "major" crops in:

- Germplasm Conservation, Characterization and Evaluation
- Enhancement, Prebreeding, Base-broadening
- Line and Cultivar Development
  - Development of Materials with Specific Characteristics of Need in Low-Input Systems
  - Development of Materials for Certain Environments and Regions
- Farming Systems Research
- Economic and Policy-oriented Research

Is the private sector ready, willing and able to take over CIMMYT's work on wheat and maize? Or CIP's work on potatoes, much less minor Andean roots and tubers? Simply posing the question provides the answer.

Above, I have also noted that the public sector internationally is needed for:

- Training. Many counties lack sufficient capacity, and, because plant breeding skills, for example, are not company-specific, few companies invest and engage in basic training.

- Developing and Securing Key Technologies and Germplasm in the Public Domain. The increasing complexities and the increasing application of intellectual property rights creates a context in which involvement of the public sector is needed simply to promote the public interest in encouraging research and development in agriculture.

I have also argued for more independence for international agricultural research institutions from the whims and long-distance micro-managing of funders. The importance of this should be self-evident.

These are some of the needs for and roles of international public agricultural research. The task before us is how to convey these needs, the urgency of them, and the tremendous benefits to be derived from investments in agricultural research to the public and to those in positions of influence.

Who will seek to build the necessary alliances? Who will develop the positive and hopeful messages? Who will articulate the dream? Who will take the lead?

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Lessons for Public Breeding from Structural Changes in the Agricultural Marketplace

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Introduction

As sociologists, our interests in seeds and breeds generally differ from plant and animal breeders – and sometimes even farmers! We are interested in the social interactions and social implications of what researchers and farmers are doing – whether it's in a fume hood or field. We are also concerned with all those who are involved in producing, processing, distributing, selling and consuming food because they may also be involved in shaping the genetics that form the basis of our food system. Why should breeders be concerned by changes in agricultural markets? What does that have to do with conserving genetic material and improving genetics across plant and animal species? We argue that one cannot understand evolution in seeds and breeds without knowledge of the changes that are occurring in the organization of the agri/food system in which they are embedded.

In recent years major changes have occurred regarding how decisions are made in the food system and who is making them. Our key concerns are who decides what food is produced, where, how, and by whom it is produced and who gets to eat it? Increasingly the decision-making in the global food system is being concentrated in the hands of fewer and fewer firms. These decisions about our food are made in the private realm of boardrooms and offices, not in the public realm of discourse, debate and dialogue. Thus, understanding the "big picture" in the agri/food system – rapidly evolving and constantly dynamic – becomes critical for all of those involved in the food system from breeders, farmers, processors, distributors, and retailers to consumers and public officials.

In this paper, we will first give a cursory overview of changes in animal genetics from a social perspective, concentrating on the how some of the decisions about domesticated animals were made and who made them. Second, we will place those changes within the context of the industrialization of agriculture. Finally, we describe the global food and agriculture system as it currently exists and suggest the barest outlines of avenues for change.

1. Changing Breeds, Changing Decisions – Shaping Animals for Us

As animals became domesticated, humans could, at least to some extent, control the mating of animals. Thus they could influence the genetic base and consequently, the characteristics that would be passed on to future generations. Although biological factors imposed major constraints on the selection of characteristics that would be expressed in the offspring in any given geographic area, social factors also became important in the evolving genetic pool. Humans could begin to select for faster animals, more powerful animals, animals that provided more or better meat or milk or a host of other characteristics. "Better" was defined by humans, but it could only be expressed to the extent it was compatible with the environment.

In diverse geographic regions sociological factors joined with biological factors in determining the genetic base for a varied array of breeds of a given species. As a result, animals of a species in one geographic area evolved to a point in which they were different from animals of the same species in other areas. These characteristics were a part of a unique gene pool and were expressed with a high degree of consistency in the offspring, the definition of a breed. The breeds of the various species that we know today were and continue to be the results of social and biological factors. The biological, and especially the sociological factors, were (and are) dynamic so that different characteristics were favored at different times, which often led to an alteration in the genetic base. If done over generations, the offspring would still meet the criteria of a breed, but might look quite different from their foreparents.

1.1 A country with few unique breeds

Even today, specific breeds of farm animals can be found in specific geographic regions in much of the world. In this, the US is somewhat unique since most farm animals in this country have a relatively short history in our geographic setting. Most breeds of animals came to this country with the European settlers and moved across the country with settlement. Since the animals evolved in the same area from where the settlers emigrated, many of our heritage breeds of pigs and chickens and current breeds of sheep, cattle and horses have "European" names linked to the geographic areas in which they were developed. Although one often equates Devon cattle with New England and Longhorns with Texas, geographic areas with pockets of a particular breed are rare in the US, often limited to what are called feral breeds that lived in geographic isolation from other breeds.

Rapid changes in agriculture in countries like the US has meant that *social* factors have become more dominant in the selection of the genetic base for the animal sector than biological factors, even though anyone who has raised farm animals knows that Mother Nature still places constraints on which genetic strains survive. Social factors have risen in importance because of research and innovations. The speed with which humans can now change the genetic makeup of farm animals in this country and around the world has rapidly increased – especially in the past few decades.

For centuries, human migration and exploration moved farm animals indigenous in one region to other regions in the world. More recent inventions, including those in transportation, have made possible the movement of breeding animals from one region to another faster and easier. For example, in the 1970s we saw the movement of dozens of "Continental Breeds" such as Simmental, Limousin, Gelbvieh, Chianina to the US "to broaden the genetic base" of the beef industry. Until then, the dominant breeds were Angus, Hereford and Shorthorn all of which had come to this country from Great Britain. However, human decisions and selection soon changed some of the most visible breed characteristics of these new breeds.

Most of the new breed associations made the decision to "speed up" the process of expanding the numbers of their new breed in the United States by allowing the use of artificial insemination and "breeding up" to purebreds. This involved breeding native cows to the "Continental Breed" bull. The half-blood females were bred back to the "Continental Breed" bull. The three-quarter blood females were again bred to the Continental bull. For most breeds the breeding of the female back to the purebred bull continued until the females were 7/8 or 15/16, and the bulls were 15/16 or 31/32. At this point the crossbreeds were considered purebred and eligible to be registered as a purebred.

I.2 Industrialization and changing breeds

There were undoubtedly many social factors leading to the selection for specific genetics in these new breeds. Aesthetics, social status, tradition, beliefs and other factors probably played a role, but major economic factors were also present. The short time some of the original breeders maintained their herds suggests their commitment to the breed was very limited. As the adoption of innovation literature suggests, there was an economic gain to be realized by being the first to introduce a new breed. In addition, there were considerable economic benefits the speculator/breeder could receive because of the federal income tax laws existing at the time.

However, underlying all of the economic opportunities were the changes taking place in the production of beef in this country as it continued toward the industrialization model. In the 1970s the old model of feeding cattle, which involved relatively small feedlots in the Midwest with forages making up a considerable portion of the feed ration, began to be replaced by large feedlots in the Great Plains that utilized highly concentrated feeds. These concentrated feeds were affordable because of the utilization of irrigation for new cropland and government farm programs. These feeds allowed the larger, slower-maturing animals to reach a heavier market size while meeting the desired quality grade. In this industrialized system, farms were specialized in grain or livestock production.

At the same time, the more industrialized slaughtering firms found that they could increase their efficiency by handling larger animals than the three dominant British Breeds could provide. Thus, the larger-frame animals provided by the Continental Breeds were in demand. However, these non-traditional colored cattle experienced major price discrimination in the market. This was undoubtedly a reason many cattle producers began selecting for black polled animals in the offspring of the crossbreeds used for the breeding up to purebreds. The result was that the red and white, horned Simmental in Europe could become a purebred, registered, black polled Simmental here. A farmer in the US can now buy a registered black polled Limousin that came to this country as a red, horned animal. One can even buy a registered black Chianina, which arrived in the US as a white animal.

The process of "breeding up," which led to the major alteration of the Continental Breeds in the US, was quite obvious and public. But what happened to the three British Breeds that were smaller, earlier maturing animals and able to reach the market grade with less grain? They changed in conformation to be much more like the Continental Breeds while keeping their old color patterns. During a performance bull sale on campus in the late 1970s, a group of students at the University of Missouri escorted a highly respected animal science geneticist to the barn to examine a very large Hereford bull. Dr. John Lasley looked over the animal and exclaimed, "Damn if I know where they found those genes in the Hereford breed."

Insiders knew that some of the Continental Breeds' genetics found their way into the genetic material of the British Breeds. Performance data collected from Missouri producers over a couple of decades showed a major jump in the weaning and yearling weight of calves, reflecting the introduction of the "new genetics" even though most of the herds appeared to be traditional breeds.[1] This data was never made public and to even suggest publicly that there might have been some gene exchange between the new breeds and the traditional breeds was heresy.
However, the uniqueness of both the Continental and traditional breeds was beginning to disappear.

Even today, at some of the most prestigious cattle shows in the country, experts in breed characteristics confidentially examine each of the steers to be shown in a specific breed class to assure they possess the distinguishing characteristics of that respective breed. In many cases the distinguishing characteristics are not at all clear. The point is that the Continental Breeds brought into this country were supposed to broaden the genetic base, but one can argue that the industrialized system based on mass production and standardization of the product has led to increased homogenization of the genetic base in US beef herds. The diversity of the beef breeds have been saved and expanded, but has the diversity of the gene pool been conserved? For example, a carcass can qualify as "Certified Angus Beef" if it is 51% black-hided.[2]

I.3 Genetic diversity, innovation and the food system

In the 1970s and 1980s, traditional beef breeding with assistance from artificial insemination was used to alter the breeds. More recent research has led to the practice of embryo transfer, cloning and DNA alteration. These techniques have greatly reduced the time required to drastically change the genetic base of farm animals. Such innovations have the potential to increase diversification of the genetic base, but the structure of the food system built on the industrialized model continually leads to standardization and loss of genetic diversity.

At the same time that research and innovation helped to speed up genetic manipulation, research and innovation in animal health care, nutrition and housing have greatly reduced the impact the natural environment has on the selection of breeds, or indeed, even where animals will be raised. Environmentally controlled buildings mute the impact of the natural environment by controlling the environment in which the animals live. On the one hand, such techniques could allow for the development of a more diversified genetic base. On the other hand, they have also made possible the use of a much smaller and

[1] Data was shown to Bill Heffernan by Dr. John Massey, livestock specialists, at the University of Missouri in the late 1980s. Dr. Massey would not allow this data to be taken from his office or to be made public.

[2] Conversation with John Tarpoff, CEO and manager of Gateway Beef Cooperative and former head of Tarpoff Meats. Tarpoff provides CAB-Prime beef to restaurants across the US.

more homogeneous gene pool that the industrialized model requires. Controlling the mini-environment in which most chickens, turkeys and hogs are now raised reduces the need for a diverse genetic pool – at least in the short term – and makes possible the mass production of a standard product that can be produced and marketed globally.

II. Industrialization, Structural Change and Decision-Making in the Food System

Industrialization, characterized by standardization, mass production and specialization, had been progressing the entire 20th century in most economic sectors of the US. However, while it did not really become visible in agriculture until after World War II, it progressed rapidly the second half of the century. It became most obvious in the production of broilers in the late 1950s, which was characterized by production contracts and vertical integration. Increasingly broilers were removed from open markets because the stages of feed production, broiler production and broiler processing came under control of the same firm. Industrial size processing facilities focused on mass production and a global marketing network required a huge amount of capital. This led to the development of large, well-financed corporations and a growing concentration of capital and control.

As the large firms grew and commanded a larger share of the market (horizontal integration), smaller firms exited. An economic structure that had been characterized by competition, in which no one buyer or seller bought or sold enough to influence the market price, began to take on characteristics that were more monopolistic. The concentration of capital and control (e.g. decision-making) were clear indicators of a changing social order. However, it was the movement of this social/economic system globally which was most striking in the last decade of the 20th century. The new social/political/economic structure of the world has transformed the way countries of the world are organized. Increasingly, economic institutions have come to dominate most other social institutions including political and educational institutions and other public bodies. All of this occurred as new discoveries limited the constraints of the environment and made possible more options in the production of food.

Throughout most of the time animals have been domesticated, most food was produced, processed and consumed by the same family in a largely self-sufficient agricultural system. Decisions were made by the family unless someone else owned the land or had claim to some other resource needed by the family. In this country, our limited experience with subsistence agriculture gave way almost immediately to selling some agricultural products in markets. These markets were crucial for a growing industrial society dependent upon excess food production by farm families. Farmers had a choice of buyers to which they could sell their products and buy their necessary inputs. Into the last half of the century, the agricultural system was still presented in most standard economic textbooks as the best example of a competitive economic system in the US. However we had already began to change by mid-century, as the vertical integration that characterized the broiler sector was joined by horizontal integration across all sectors.

II.1 Changes in marketplace structure and control of genetics

In 1999, we started to diagram emerging food system clusters. We started these clusters with the five dominant firms that control the genetic material for major grain and oil crops raised in the US. They are, of course, the five major global firms in seed production as well. These genetic firms captured their dominant position after intellectual property rights (IPR) were given to firms and products of biotechnology were becoming commercially available. The argument for IPR was that for firms to invest in such expensive research, they must be assured they could receive considerable economic benefits. From the outset it was obvious that only the most highly capitalized firms, which included pharmaceutical firms, could afford such expensive research. Since research leading to the introduction of biotechnology was perceived as the future of crop breeding and production, experts predicted a grim future for seed firms without access to biotechnology. This prompted smaller firms without such access to capital – or even large firms like Cargill – to literally run to one the five firms and ask to be bought. The number of seed firms in the US dropped considerably in a couple of years.

The seed firms are not large compared to some of the other firms in the clusters, especially the retail firms, but they do control the genes of life. They cannot be left out of the emerging global food system. They are major players. Today five firms dominate the genetics for most of the crops that are grown world-wide – Bayer (which just acquired Aventis), Monsanto, DuPont (which owns Pioneer), Dow and Syngenta (which is the merger of Novartis' and Astra Zeneca's seed divisions).

In our diagrams, we did not include the firms that control the genetics of animals used in the industrialized global agriculture. Like the crop breeding firms, their numbers are very limited in the different species. In most of the commercial farm animal species three or four firms will have 50 to 90 percent of the market share as in the case of commercial turkeys. Dairy cows present a different arrangement. Although control and ownership of the breeding stock is still relatively dispersed among dairy farms, in the Holstein breed – which makes up over 90 percent of the dairy cows in this country – over 60 percent of the cows come from four family lines. These lines are disproportionately represented by the firms providing semen and embryos for transfer. Clearly in a complete diagram of the food system clusters, farm animal genetic firms need to be included. One of the points we would make is that as the private sector has taken over the major control of genetic material, it has been increasingly difficult to obtain public information on these sectors.

II.2 From genetics onward

If we look at another sector in the food system – the so-called "protein sector" – we see the same sort of concentration occurring in the US, and to some extent globally. Today, the largest protein firm in the world, Tyson Foods, is the number one beef and chicken processor and number two pork processor in the United States. Smithfield's recent acquisition of Farmland Foods consolidates its hold on the number one spot in pork packing. Cargill's Excel meat processing company is the number two packer in beef and number four packer in pork. ConAgra, until recently a large player in the protein sector, sold it's pork and beef concerns to an investment firm that operates under the name Swift & Company, while retaining a 46% share in the new enterprise (*Feedstuffs* 9/23/02). In addition, ConAgra recently sold their poultry operations to Pilgrim's Pride, placing that firm second in the number of broilers processed in the US (*Feedstuffs*, 6/16/03). The same firms show up as large processors across the globe, where Smithfield is the largest pork processor in Poland, number two in France, with large production facilities on the ground in Brazil and Mexico. Cargill is a large meat processor in both Canada and Australia.

Grains are arguably the commodity that has been the most globalized for the longest period of time. In the US, four firms – Cargill, Cenex Harvest States, ADM and General Mills[3] – control 60% of the terminal grain handling facilities (2002 Grain and Milling Annual), while Cargill and ADM (combined with Zen-Noh) export 81% of US Corn and 65% of US soybeans (*farmindustrynews.com*, March 01). Bunge became the largest oilseed processor in the world with its purchase of Cereol in late 2002, and reigns supreme with ADM and Cargill in soybean processing in Brazil.

In 1999, we documented three emerging food chain clusters which included joint ventures and long term agreements that are mechanisms used by firms to "outsource" some of their operations. The clusters were Cargill/Monsanto, ConAgra and Novartis/ADM (see diagrams 1-3). As noted, we started with access to genetic material – the seed firms – and worked down through grain and animal procurement, processing and food manufacturing. The firms named above formed alliances to dominate the food system from seed to shelf. We stand by these food chain clusters today, although the system is dynamic and the clusters have changed. For instance, ConAgra has exited much of the middle by selling its meat and poultry lines and shopping its agricultural input concerns like United AgriProduts. Still, their relationship with DuPont has deepened, and the firm remains a formidable food manufacturer. Similarly, the Novartis/ADM cluster has undergone significant changes with ADM leasing Farmland's grain operations, Novartis combining seed and chemical operations with AstraZeneca, and IBP ceasing to exist as a stand-alone company. Cargill has developed joint ventures with Dow and Hormel, while restructuring itself

[3] Cargill and Cenex-Harvest States are now involved in a joint grain marketing venture.

to become more than a commodity trader. Other firms, like Bunge, Tyson and Smithfield will likely form at least another one or two more food chain clusters.

More importantly, the changes taking place in global retailing will have major impacts on what happens to the agricultural marketplace, and by extension what happens to farms and the diversity of the plants and animals that make up those farms. Currently, about five to six retailing firms are emerging on the global level, with Wal-Mart a key contender. (The others are European including Ahold from the Netherlands, Carrefour from France, and Tesco from the United Kingdom.) Every continent has seen the penetration of the giants of food retailing, even into the poorest of the poor regions (Weatherspoon and Reardon, 2003; Reardon and Berdegué, 2002). As these firms gain market power, they will be able to dictate price back to the processors and on through the supply chain. Moreover, these firms will be able to specify the genetics of the grains, fruits, vegetables and meats that they sell given their relationship with the final consumer (Marsden, 2003).

This sort of globalization might not be possible without the accompanying work to liberalize trade. Trade liberalization means that national governments make fewer and fewer decisions regarding government policies related to the food system, such as the flow of goods and services into and out of their country. Instead of governments making major policy related to their food system, global firms make decisions about a country's food system. This is a significant change with major social implications.

III. Implications for Farmers, Consumers and Everyone Between

What have these changes in the structure of agriculture meant to US farms? As the marketplace for farm products has consolidated, farms have grown larger and more specialized. For genetic diversity and ecological systems as a whole, this should be a grave concern. For instance, some authors argue that the US Midwest now represents a large ecological sacrifice area (Jackson and Jackson, 2001) with farms consisting of nothing but corn, beans, and confined animal feeding operations. Research carried out by students at Iowa State University showed that Iowa farms were much more diversified in the early part of the last century. In 1935, seven different commodities were produced on at least 50% of Iowa farms; by 1997 this was reduced to two – corn and beans (see Table 1). A similar story can be told in Missouri where only 5% of farms were producing hogs & pigs in 1997, down from 43% in 1964, and only 4% of farms were dairying, down from 39% in 1964 (see Table 2).

While consolidation in the food system has clearly had negative ecological impacts, the real issue raised by the globalizing structure of the food system is who makes the decisions about what is produced and consumed and on what basis these decisions are made. The results of our research suggest that a relatively small number of firms, which continues to decrease, make a growing number of the major decisions in the food system. These are the firms deciding what animal and plant genes are to be used and which have no utility today.

More importantly, this structure means that decisions about who produces our food, what food is produced, how it is produced and who gets to eat that food have been steadily moving from the more public realm of debate and dialogue to the more private realm of corporation boardrooms and trade liberalization talks. As the structure of the marketplace has changed for farmers, the decisions they can make about what plants and animals to use in their farming operation has been severely constrained. The vast amount of food grown on today's farms is already destined to move inexorably through one of the food chain clusters that we have documented. In addition, consumers who rely on major supermarkets, chain restaurants or institutional food services to supply their food needs face more limited choices, a counterintuitive argument given the vast array of produce available in supermarkets. However, finding "heritage" turkeys at Thanksgiving, or homegrown heirloom tomatoes at their harvest peak is nigh impossible outside farmers' markets or specialty retailers.

III.1 The role of corporations and governments

It is important to understand that at present, firms have a very specific role in the food system. Corporations are chartered to make money for their stockholders. For several years ConAgra indicated in their annual report that their mission is "to increase the wealth of their stockholders."

This is the honest goal of all corporations and it permeates the activities and decision-making of such organizations. The firm's decisions are based on what generates the most income for the firm. The role of a government, on the other the hand, is to enhance the well-being of its citizens. In food and agriculture, decisions are now made in the private sector – where profit generation is the goal – rather than by nation-states enhancing the well-being of their citizens.

While this change in decision-makers in the global food system has important implications for ecological diversity, rural development, agricultural structure and public health, it has special implications for those with low incomes. Over forty percent of the world's population has a daily income of two dollars or less, which translates into an annual income of less than eight hundred dollars per year. Food firms focused on increasing their income to stockholders will not be very interested in focusing their efforts on these people when they can focus on affluent consumers with thousands of dollars a year to spend. A question to be asked is: who is going to feed the one half of the world's population that has low incomes?

Given the state of our agricultural economy, another question that may be posed is: Do we need US farmers? Steven Blank, an economist from the University of California Davis, has suggested that consumers in the US could buy their food from poorer countries cheaper than it can be produced in the US. Thus, he proposes we buy US food from poor countries and use our land for urban expansion and recreation. This further supposes that regardless of where the food is produced, consumption of the food will depend upon one's income.

Whatever the merits advanced in defense of the global economy for other sectors of the economy, the question to be raised as it relates to food is whether adequate food is a right or a privilege. The evolving food systems suggests that those who have a good income will be able to obtain food regardless of where they live and where or how the food is produced, but those without adequate incomes will be left out. Corporations are not chartered to be charitable organizations.

Another question to be raised: is the food system so unique that it requires special policies? We think that inadvertently the World Trade Organization is just now beginning to understand that food is different than other goods and services that are exchanged in the global economy. As the country representatives gathered in Cancun recently, agriculture, which we prefer to think as food, was the focus of major disharmony. Some argue the future of WTO may be at stake if this issue cannot be resolved. Are they are willing to admit food is unique or face the demise of the WTO?

IV. Is The Food System As Described Inevitable?

In the face of such overwhelming odds, is there any chance of changing the course of the global food system? Many scholars and others argue that the system described above is the inevitable outcome of "natural" forces. However, we have documented that there are a host of biological, social and economic factors that have produced our present system. A system that is humanly created can thus be changed, provided the majority of people seek that change.

There are some small steps that we can all take toward creating a more ecologically diverse, equitable, and sustainable system. First it is important for public dialogue and debate about what our food system does and should look like to take place. Historically, this debate has taken place in the academy. Public discourse about genetic diversity and social/economic structure has been constrained in recent years because of privatization of knowledge in the academy through funding streams, licensing agreements and intellectual property rights. However, there is still space for dialogue and debate that must be utilized by plant and animal breeders based in public institutions like USDA and land-grant universities. Other disciplines – like philosophy, law, humanities and the social sciences must also be engaged.

While talking in the academy is one small step, a second one is building public support for genetic diversity through outreach and involvement with non-profit organizations. At Thanksgiving time, Slow Food USA, a consumer group that advocates enjoyment and preservation of artisan foods and foodways, will match hundreds of eaters seeking "heritage" turkeys with farmers and processors who can provide those turkeys. Slow Food members understand that genetic diversity is key to a unique and quality food supply and are willing to support farmers who want to preserve genetics as well as a way of life. Affinity groups – from Slow Food to large environmental organizations – must have the knowledge of what is happening to the very basic building blocks of our food supply which requires articulating plant and animal breeding issues in terms that everyone can embrace.

Third, public policies that support gene banks, and promote heritage breeds and seed saving must be articulated and promoted. More importantly, policies are needed that can shape and support alternative markets for a diverse array of plants and animals. Existing competitive research grants and rural development monies should try to link value-added agriculture and genetic preservation together.

Our job as concerned activists and academics is to increase the public awareness and understanding of the crucial issues for genetic diversity that result from our current participation in the food system, and to suggest steps for changes. With this public awareness and then support, the system as currently manifested is no longer inevitable.

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Table 1: Trends toward specialization in Iowa

US Census of Agriculture	**1935**	**1954**	**1978**	**1997**
Commodities that were produced on at least 50% of more of Iowa Farms	Cattle, Horses, Chickens, Corn, Hogs, Hay, Potatoes, Apples, Oats	Corn, Cattle, Oats, Chickens, Hogs, Hay	Corn, Soybeans, Cattle, Hay, Hogs	Corn, Soybeans
Commodities that were produced on between 15% and 50% of Iowa Farms	Cherries, Grapes, Plums, Sheep, Peaches, Pears	Horses, Soybeans, Potatos and Sheep	Oats	Hay, Cattle, Hogs
Commodities that were produced on between 1% and 15% of Iowa Farms	Mules, Ducks, Wheat, Geese, Sorghum, Barley, Red Clover, Strawberries, Soybeans, Raspberries, Bees, Timothy, Turkey, Rye, Popcorn, Sweet Corn, Sweet Clover, Goats	Ducks, Apples, Cherries, Peaches, Goats, Grapes, Pears, Plums, Wheat, Red Clover, Geese, Popcorn, Timothy, Sweet Potatos, Sweet Corn, Turkeys	Horses, Chickens, Sheep, Wheat, Goats, Ducks	Oats, Horses, Sheep, Chickens Goats

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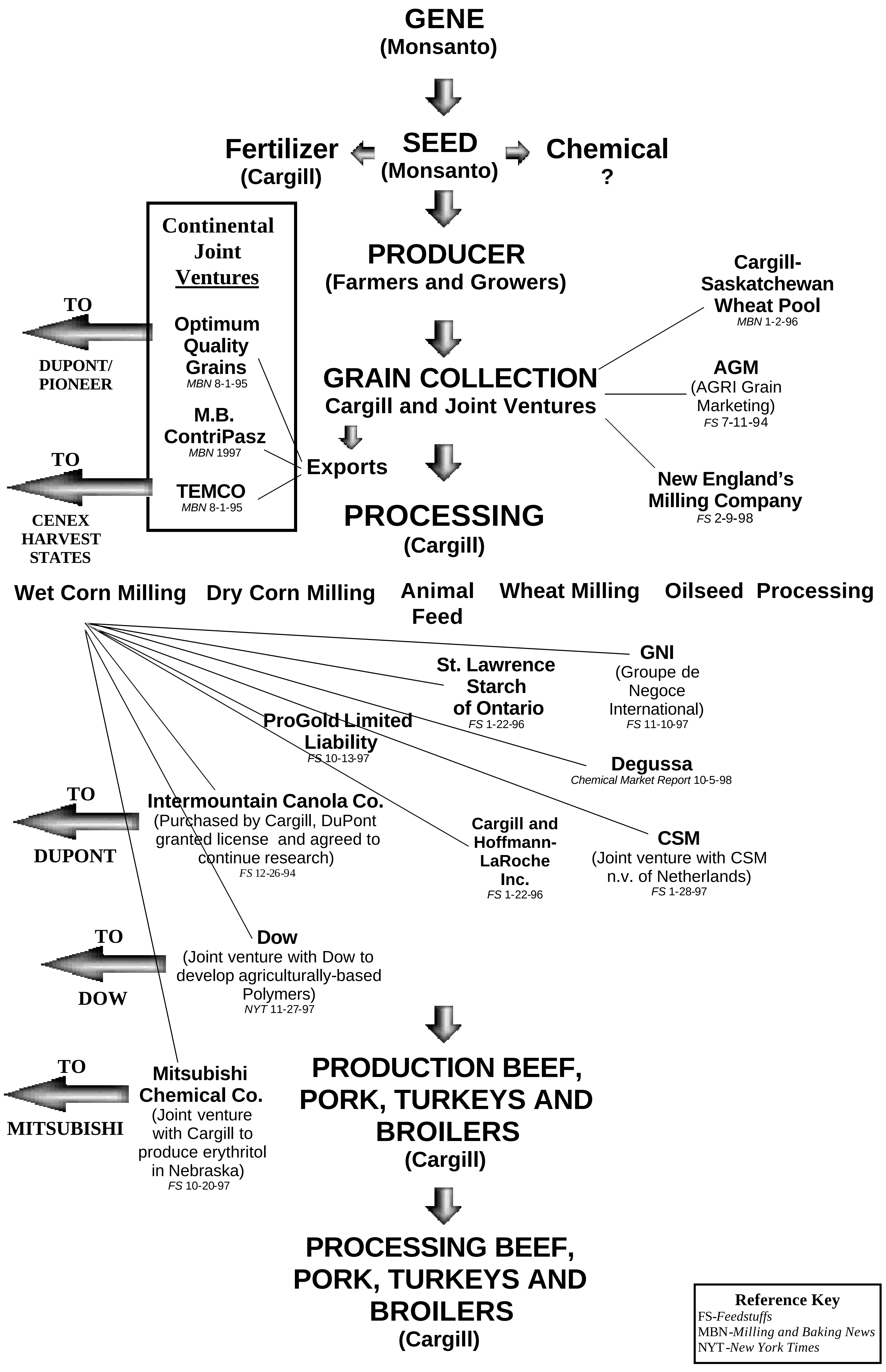
Table 2: Trends toward specialization in Missouri farms

US Census of Agriculture	**1997**	**% of Farms**	**1964**	**% of Farms**
Number of MO Farms	98,860	100%	147,315	100%
Beef Cows	57,935	59%	89,163	61%
Hay -- including silage, green chop, small grains	57,483	58%	73,913	54%
Corn	18,417	19%	64,423	44%
Hogs & Pigs	5,419	5%	62,895	43%
Layers & Pullets	3,707	4%	62,044	42%
Milk Cows	4,175	4%	57,398	39%
Wheat	12,394	13%	45,707	31%
Soybeans	24,201	24%	43,870	30%
Oats	1,254	1%	19,273	13%
Sorghum	3,566	4%	7,108	5%
Broilers	451	0.46%	559	0.38%

Cargill/Monsanto
Joint Ventures and Strategic Alliances



ConAgra
Joint Ventures and Strategic Alliances

Distribution of Chemicals, Fertilizer and Seed
(ConAgra (United Agri Products))

PRODUCER
(Farmers)

GRAIN COLLECTION
(ConAgra

Exports

Joint Ventures

ADM
(Kalama Export)

Farmland Industries
(Three elevators)

Harvest States
(Three terminals, two exports)
FS 9-12-94

ConAgra purchases high-oil corn seed from DuPont; contracts with farmers; buys back for poultry feed.
NYT 10-30-97

PROCESSING
(ConAgra)

Dry Corn Milling · **Wheat Milling** · **Oat Milling** · **Animal Feed** · **Soybean Processing** · **Barley Malting** · **Potatoes (Lamb-Weston)**

PRODUCTION BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)

PROCESSING BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)

FURTHER PROCESSED BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)

GROCERY SHELF AND REFRIGERATED FOODS
(ConAgra)

Meijer Frozen Foods
(Preeminent Supplier of potato products throughout Europe)
ConAgra Annual Report

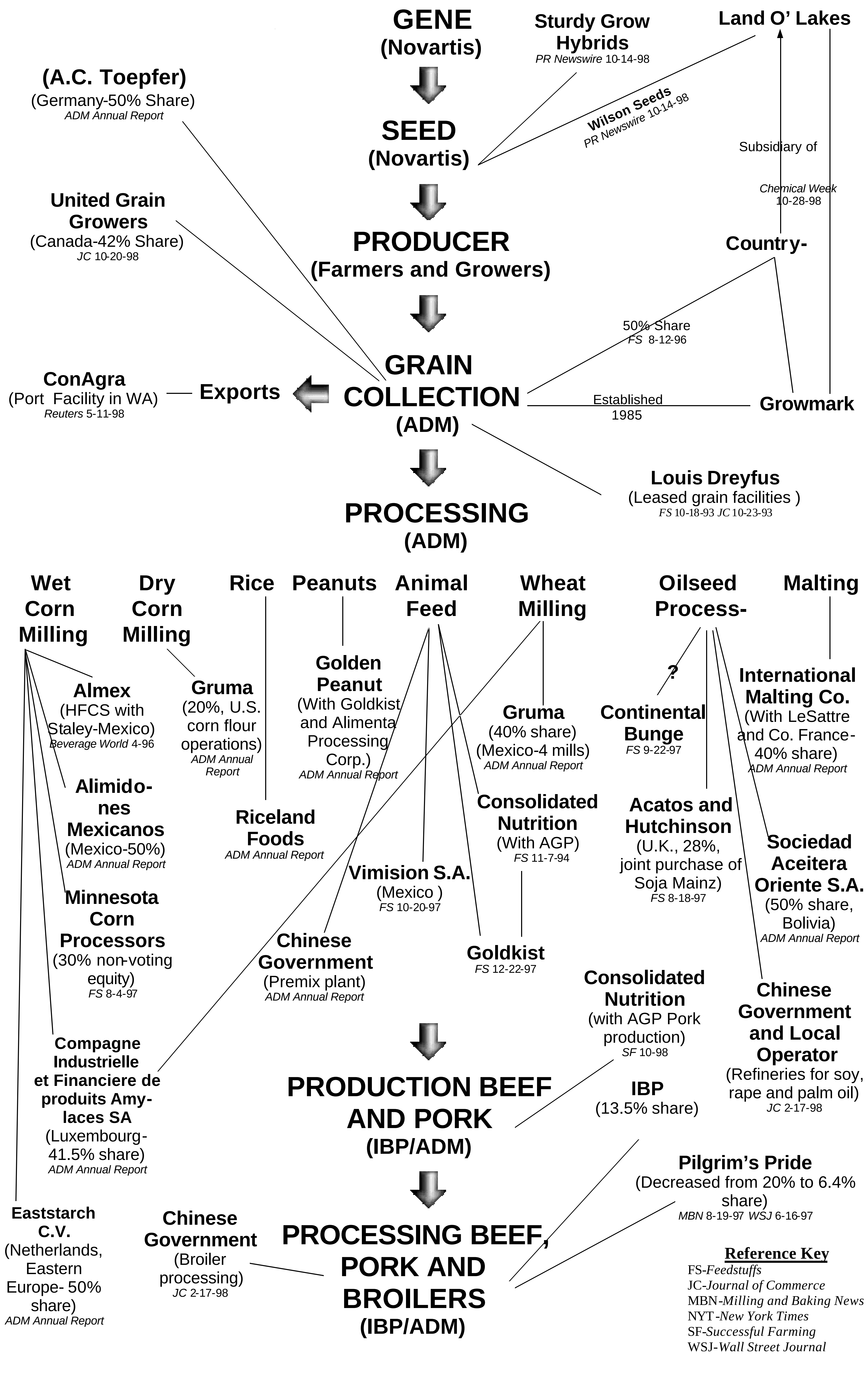
Tiger Oats Limited
(South African Company)
ConAgra Annual Report

ITC Agro-Tech Ltd.
(Commodity oil business in India)
ConAgra Annual Report

Verde Valle, S.A.
(Branded grocery products-Mexico)
ConAgra Annual Report

Reference Key
FS-*Feedstuffs*
NYT -*New York Times*

Novartis/Archer Daniels Midland (ADM)
Joint Ventures and Strategic Alliances



What Is Plant Breeding?

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"The great power of this principle of selection is not hypothetical."

Charles Darwin, On the Origin of Species

My assigned task this morning is to provide some background on the practice of plant breeding, providing a common foundation for the participants. Given the breadth of the subject and the range of experiences of the participants I will concentrate on the key biological features of plant breeding. In addition I will spend some time discussing what makes plant breeding different from other crop improvement technologies and some of the implications of these differences. Numerous excellent texts on plant breeding are available and these should be referred to for specific methods and practices (Allard, 1999; Fehr, 1987; Simmonds and Smart, 1999)

It is not my intention to compare plant breeding and genome engineering (transformation and developing genomic applications). However, genome engineering is now the dominant paradigm, and engineering and breeding are frequently compared, especially in literature promoting engineering. So there are occasions, especially when dealing with common misstatements regarding plant breeding, when I have found it necessary to compare the two processes.

What Plant Breeding Is

Key feature:

Distilled to its essence, plant breeding is human directed selection in genetically variable populations of plants. Selection based on the phenotype is the key feature of plant breeding programs. The reliance on selection, both artificial and natural, differentiates plant breeding from other technologies. The target population must be genetically variable, otherwise no change can occur. If successful, selection results in a population that is phenotypically and genetically different from the starting population.

Principles and Implications of Selection

The power and implications of selection cannot be over emphasized. Earth's biological diversity is due to natural selection, and diversity of our domesticated plants and animals is due to artificial selection. Darwin, in developing the theory of natural selection, relied heavily on the knowledge and experiences of plant and animal breeders. Darwin used examples from plant and animal breeding to demonstrate the feasibility of natural selection (Darwin, 1859). Given the familiarity of Victorian England's intellectual class with domesticated species, these examples were persuasive. Today, most people in the industrial world are distant from both agriculture and nature; thus, it is unsurprising that few understand the power of selection and its role in our world.

The raw material for selection is the genetic variation created by mutations. As selection is applied, plants with favorable alleles are chosen. If the non-selected individuals are removed from the population, the remaining population will have a different gene frequency from that of the original population and selection will have been effective in improving the average performance of the population. But, no new individuals or genotypes were created. Everyone, including anti-evolutionists, understands and accepts this eliminatory aspect of selection.

What Darwin recognized, and plant breeders harness is the creative power of selection. If only the selected plants are allowed to sexually reproduce, new genotypes will occur in the following generation many of which have never existed before. If the process is repeated for a number of generations, then favorable alleles at many loci affecting the selected trait will accumulate in the population. Through sexual reproduction, those alleles will be recombined, often resulting in completely novel and unexpected individuals. As Darwin (1859) said

> "The key is man's power of accumulative selection: nature gives successive variations; man adds them up in certain directions useful to him. In this sense he may be said to make for himself useful breeds."

It is crucial to recognize the creative aspect of selection. It is my opinion most scientists, including many biologists, still do not recognize Darwin's key insight - the creative power of selection.

The creative power of selection is the key feature of plant breeding and what makes plant (and animal) breeding unique among human technologies. It is this power that distinguishes plant breeding from genomic engineering and, in the long run, makes breeding so powerful.

Frequently, critics of plant breeding (proponents of engineering) suggest that the products of plant breeding are random and unpredictable. Usually these allegations occur when people are defending the safety of genome engineering and suggest that, in comparison to plant breeding, genomic engineering is precise and scientific. The concept of randomness and imprecision is due to a misunderstanding of the process of plant breeding and confusion of biological levels of organization. Genetic recombination is random, but the effect of selection is not. If we select for resistance to rust we get rust resistance. If we select for higher yields we get increased yields. If we select for more tender sweet corn we get tender corn. The direct effect of selection is remarkably predictable and precise.

The direct effects of selection are highly predictable. However, what makes selection immensely interesting and valuable are the unpredictable correlated or indirect effects. Such effects result in novel, useful, and sometimes wonderful changes that could not have been predicted prior to the beginning of the selection program. The retrospective studies of the changes in Corn Belt Dent maize hybrids by Duvick et al (2004) provide many excellent examples.

Selection for harvestable yield has resulted in some correlated changes that one might have predicted at the outset. Since harvestable yield includes only those ears that can be harvested by a machine, one would predict that standability (root and stalk strength) would be improved and indeed this is the case (Duvick et al, 2004). One might also have predicted that ear and kernel size, leaf number, and photosynthetic capacity would increase. However, these traits changed only slightly if at all (Duvick et al, 2004; Tollenaar and Wu, 1999). It is unlikely that one would have predicted that tassels would have become much smaller or that leaf angle would have changed, but these changes were strongly correlated with years the hybrids were released. One may have predicted that stress tolerance would increase, which it did, but one would have been even more likely to predict that yield capacity and heterosis would have increased, which haven't.

The point is we know what is biologically important <u>after</u> the fact. If in 1930, genomic engineers had chosen to improve yield capacity and increase ear size, would they have made the same gains as plant breeders did simply selecting for yield? If, in 2003, genomic engineers view the results of Duvick et al. (2004) and decide to decrease tassel size and increase stress tolerance, are these the best decisions for the new environments and germplasm of the new century? The beauty of selection is that humans don't make those choices and retrospective information isn't needed. We simply select the phenotypes we want and let the genome interact with the environment to give us new organisms that yield more, taste better, and are healthier.

Selection also results in changes the genetic base of the crop in unpredictable ways. In the 1930s, at the beginning of the hybrid corn era, there were hundreds of open-pollinated corn cultivars. It would have been impossible to predict which ones would be most successful in the future. Indeed by the 1970s, many were surprised that a relatively obscure cultivar "Lancaster Surecrop" was apparently the most important germplasm source (Sprague, 1972; Zuber, 1976). And who would have predicted in the 1970s that Lancaster would be relatively unimportant in 2000 (Troyer 2000)? Overtime, selection for increased yield changed the germplasm that contributed to high yields. The environment and gene pool favored Lancaster in the first half of the hybrid era, but changes in crop management made

Lancaster germplasm less favored in the last 30 years.

If genomic engineers had been able to engineer the corn plant in 1970 they would have devoted much of their resources to Lancaster germplasm. This decision would have been based on a retrospective look at what had occurred between 1930 and 1970. However, it now appears that heavy investment in Lancaster would have been the wrong choice and severely limited potential gain.

The key thing to recognize is, while selection predictably has resulted in high yields, the ways in which the changes occurred were entirely unpredictable. And it is important that plant breeders were ready and able to capitalize on these unpredictable occurrences. Henry A. Wallace the founder of Pioneer Hi-Bred said

> ”There is no substitute for the man who can observe and who lives so closely with his material that he can recognize a lucky break when he sees it.” (in Smith et al, 1996)

Selection results in adaptation to the local environment while selecting for the trait of interest. This may be obvious for a trait strongly influenced by the environment, such as yield. But this is true for any trait as long as the breeder also selects for overall performance. Since the breeding process is repeated each growing season, selection identifies genotypes that are adapted to the current abiotic and biotic environment. If the climate is becoming warmer over time then genotypes adapted to warmer temperatures will be selected. Likewise, if a new race of a pathogen becomes prevalent, the newly selected individuals will be relatively more resistant, than plants not developed under those conditions. This presumes that the original germplasm had genetic variability for temperature response or disease resistance.

Selection also results in adaptation of the internal environment (genome) to a new trait. For example if we wish to develop a high sugar, high yielding sweet corn line, we would cross a source with the high sugar gene by a high yielding, low sugar line. We know from experience that the high sugar gene is nearly lethal in the high yield background. But by selection for high sugar, high yield, and high viability at the same time over a number of generations, selection and recombination will result in gene combinations that produce a viable product.

The contrast between selection and engineering regarding adaptation to the internal or external environment is stark. Given adequate genetic variability, selection adapts the evolving genome to the environment. Engineering needs to know in advance what the coming climate or pests will be. Likewise, the engineering approach to develop high sugar high yield lines would be to simply transform the high sugar gene into a number of high yield lines until a viable combination is found. This could hardly be considered more precise or predictable than selection.

Critics of plant breeding often suggest that plant breeding is slow, requiring great patience and persistence and that plant breeders are stolid creatures, doggedly sorting through material. While these misperceptions are traceable to the internal mythology of plant breeding, they are false. If it were true how could the life span of modern corn hybrids be between three and five years? Selection rapidly changes populations and creates phenotypes that have never before existed. Plant breeders are impatient, anxiously awaiting the products of an exciting cross, the latest trial data, or the opening of a flower for pollination. Speed does depend on a number of factors including life cycles, genetic variation, and intensity of selection. Very intense selection can produce dramatic changes in a few generations, but may deplete genetic variation for the trait of interest. Mild selection will result in more gradual but sustainable change.

Regarding the contention that plant breeding is unscientific. This appears to be due to a general discomfort with the fact that plant breeders do not need to understand how a trait works (biochemically or physiologically) to successfully alter the trait. What this ignores is that plant breeders are experts in the science of selection and allied disciplines, especially statistics. If the definition of science is a way of knowing based on the process of proposing and testing hypotheses, plant breeders may be world champions. Each yield trial consists of dozens of hypotheses, tested in highly replicated, well-designed experiments in multiple environments. Plant breeding is a science-based technology.

Mechanics of plant breeding:

Methods, tools, time frames, and types of cultivars vary widely depending on the lifecycle, reproductive biology, and level of domestication of a particular species. In maize, which is relatively easy to cross pollinate and emasculate, US breeders use the inbred/hybrid breeding method and complicated mating designs, while in soybeans, which are much more difficult to hand pollinate, breeders develop pure line cultivars and use methods that minimize mechanical crossing. Wheat breeding is highly mechanized, while the breeding of flowers such as the day lily is almost completely unmechanized. Snap bean breeders may be able to get five generations per year, and elm breeders may not get that many in their entire career.

While life cycles and resources (greenhouses, winter nurseries) determine the number of generations per year, the number of growing seasons per year in the intended area of release determines the speed with which new cultivars may be evaluated. Traditionally plant breeders have been conservative in their evaluation of new products emphasizing multiple years and locations of evaluation prior to the release of new cultivars. This emphasis makes good business sense because risk adverse growers will stop buying failed products and avoid companies that have marketed failed brands. Most plant breeders believe extensive testing is important, because implicit in their Land Grant University education was a sense of service and the concomitant duty to protect the growers. Unfortunately, as investment in plant improvement has increased, the testing process has sometimes been cut short in a rush to get new products to market. Usually public breeders are not under the same pressure to rush new products to market. However, as public support has decreased, the pressure on public breeders to get products to market has increased.

Objectives:

Objectives vary widely. Take, for example, a single species; maize. The sole objective of many US maize breeders is harvestable yield; maize breeders in Mexico are concerned with yield and also quality factors for making tortillas. Sweet corn breeders need to be concerned with many quality factors including flavor, texture, and tenderness, as well as ear and husk appearance and even how easily the silks are removed from the ear. Popcorn breeders are interested in popping volume, tenderness, flavor, and flake shape. Maize silage breeders work on forage quality and may measure yield as “milk per acre”.

The main objective of private corporations is to make profit for the owners/investors. This is generally done by developing cultivars that sell large volumes of seed. Public breeders are generally less concerned about sales volume and may be more interested in developing cultivars that actually reduce seed sales, such as long lived perennials or cultivars from which the farmer may save seed such as pure lines and open-pollinated cultivars. Private corporations invest resources in a few major crops, which are most profitable. This along with regulatory and economic factors contributes to the decline in on farm crop species diversity. Less-favored crops are left to public breeders who are often responsible for multiple crops and have very limited resources. Many crops have a fraction of a full time equivalent responsible for their improvement (Frey, 1996). Improved cultivars of these less-favored crops are needed to increase on-farm species diversity (along with changes in US farm programs.)

Adaptation:

All cultivars must be adapted to the environment in which the cultivar will be grown. New cultivars need to tolerate the normal range of pests and climatic conditions. This requirement is the basis for one of the most basic principles from introductory plant breeding classes **- Breed in the area where the new cultivar will be grown.** At the very least, cultivars should be evaluated for multiple years and in numerous environments prior to release. Sometimes, due to financial considerations, breeders attempt to breed in an environment different from the target region and/or short cut testing, usually with very negative results for both the farmer and seed producer.

The size of the intended area of adaptation varies greatly. Large hybrid corn companies target widely adapted hybrids that, within a maturity zone, may be grown from Nebraska to Delaware. Farmer-breeders in western Mexico may target a specific altitude in a single valley. Widely adapted cultivars tend to be more stable over a wide range of environmental conditions, but may not suit the needs of specialized market niches or environments. Size of the target area is a function of economics, both in terms of sales and costs. Large companies prefer wide adaptation to gain efficiencies in inventory management, marketing, and seed production. But breeding for wide adaptation requires greater investment in breeding programs. Small seed companies and farmer-breeders can develop cultivars well suited to local conditions, but the size of the market may not support even a small breeding program. Public plant breeding programs tend to focus more on local or regional adaptation and local markets and production systems. As consolidation continues in the seed industry and companies abandon markets and regions, the need and opportunities for serving local communities increase. But at the same time, the number of public breeders declines, and seed production and distribution infrastructure are lost.

What Does a Plant Breeder do?

A plant breeder develops and implements a program designed to produce improved crop cultivars. Depending on the organization in which the breeder works, the breeder may be responsible for managing a research station, raising funds, and even selling seed. I will concentrate on the plant breeding aspects of the breeder's job.

The plant breeder a) chooses germplasm to form the basis of the breeding program, b) plans crosses to create genetic variation, c) manipulates the plant reproduction, d) develops and applies selection protocols, e) plans and implements a cultivar testing program, f) collects and analyzes data, and g) decides which cultivars should be advanced.

All of these functions are important for a successful plant breeding program but some functions can be quickly picked up by any novice, while other functions including decisions on parental germplasm, selection protocols, and germplasm evaluation require years of experience. It is this experience that is often called the "breeder's art" or "eye". "*Breeders universally depend on experience and art more than genetics*." Duvick (1996). But it is art in the sense of skill. Experience becomes art (skill) when knowledge becomes subconscious. The experienced plant breeder has observed hundreds or thousands of germplasm sources and crosses and develops an understanding of how certain germplasm sources perform in specific environments and crosses. Experienced breeders have seen tens of thousands of phenotypes and develop a set of selection criteria that become subconscious. An experienced breeder will make a decision based on a quick look at a plant, a plot, or even an entire trial. When asked what criteria are being used for such decisions it may take some time for the breeder to fully articulate the key traits, but those traits have become key based on repeated experience. Darwin (1859) summed it up by writing

> "Not one man in a thousand has accuracy of eye or judgment to become an eminent breeder. If gifted with these qualities, and he studies his subject for years, and devotes his lifetime to it with indomitable perseverance, he will succeed, and may make great improvements: if he wants any one of these qualities he will assuredly fail."

None of this is to suggest that plant breeding is unscientific. I do suggest that successful breeders spend years in the field with their crop and they develop "a feeling for the organism" as has been said of the maize geneticist Barbara McClintock (Keller, 1983).

Education:

Plant breeders are educated as biological scientists. In the past, most plant breeders received their undergraduate education at Land Grant Colleges of Agriculture, with training in crop and soil sciences, entomology, plant pathology, genetics, chemistry, botany, and some agricultural economics. In graduate school they would take plant breeding, cytogenetics, advanced genetics, plant physiology, quantitative genetics, and statistics. Of these courses, statistics and plant breeding would have been of the greatest direct use for the breeder, with other areas being more or less important depending upon the crop and the breeding objectives.

Today the situation has changed. Graduate students are entering from a wider array of institutions. Fewer students have a solid background in agricultural science from their undergraduate programs and there is not enough space in the graduate curriculum to correct these deficiencies. Furthermore, molecular biology and biochemistry courses have become a standard part of the curriculum. With new additions to the curriculum and no additional time, something has to give and these may be the traditional plant breeding core courses such as statistics, quantitative genetics, and cytogenetics. The courses that graduate students take depends on their interest, that of their advisor, and the academic strength of the institution but the trends remain. Clearly the decline in quantitative/population thinking does not bode well for a discipline that is based on manipulation of gene frequencies in genetically variable populations over multiple environments.

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Will Plant Breeders Continue to Exist?

In any discussion of the impact of plant genomic engineering on plant improvement, it will be asserted that plant breeding will continue to be extremely important and that without plant breeding genomic engineering cannot be successful. Unfortunately I disagree. The world will not come to an end if traditional plant breeders disappear and it is clear the disappearance is well underway. Don't misunderstand, the planet will be poorer for the loss of plant breeders, but it will keep on spinning.

To explain my belief, a definition of plant breeder is required. I could use Darwin's description, but I will be more concise. Based on the discussion above I define a plant breeder as one who develops and implements phenotypic selection programs and spends enough time with the plants so as to gain a feeling for the organism. Scientists with the title "plant breeder" may continue to exist but, unless trends change, professionals who meet this definition will continue to disappear.

There are a number of reasons to believe the disappearance of "selectionists" will come to pass.

1. This has happened to other disciplines dealing with the whole plant, physiologists, anatomists, pathologists, and to a lesser extent agronomists and horticulturalists. If the titles still exist the disciplines have morphed into essentially new disciplines. I am not opposed to this. It is the way science and culture evolve. But let us not kid ourselves and think it can't happen to plant breeding. Each of these groups believed they were necessary and eventually the "new folk" would figure out how important their knowledge was and come looking for advice or expertise. Wrong! These groups became marginalized in terms of funding and science. Today if a molecular geneticist is interested in the anatomy of the coleoptile, they pull Esau (1965) off the shelf and cobble together what they need to know. The results may not always be pretty or efficient but they will be successful as far as peer review goes, because none of the reviewers will be anatomists.
2. As outlined above, professionals trained in plant breeding today do not have the same background or advanced classes as that of the selectionists of the past. They are weaker in agricultural sciences, quantitative thinking, whole plant biology, and selection theory.
3. Supervisors may sincerely believe that plant breeders are needed. But what is the supervisor's background? How do they define plant breeder? Do they understand the power and role of selection? Do they know what it takes to gain a feeling for the organism?
4. The reigning engineering paradigm is in direct opposition to the selectionist paradigm. Engineering suggests that we can find out what all the genes do and then put them together in the optimal way. Selectionists apply selection and let nature and the organism create an array of

solutions any number of which will be useful, some in unique and unexpected ways.

Plant improvement can and will occur following the engineering paradigm. Gains may not be as rapid, cost efficient, successful, or to my mind interesting as those made via selection, but gains will be made. Plant breeders will exist as technicians for engineering programs.

Why should plant breeding be supported by taxes?

Why should plant breeding be supported in the public sector? Or, how does plant breeding differ from other industries? If we attempt to convince taxpayers that they should support plant breeding we need to have good answers for these questions.

- Food Security: Plant breeding decisions determine the future of the world's food supply. Placing the responsibility for the world's crop germplasm and plant improvement in the hands of a few companies is bad public policy. The primary goal of private corporations is to make profit, and even in the case of the most civic-minded corporations, this goal will be at odds with certain public needs. Even if we assume that the one or two companies controlling a crop were completely altruistic, it is extremely dangerous to have so few people making decisions that will determine the future of a crop. Even well intentioned people make mistakes. The future of our food supply requires genetic diversity but also demands a diversity of decision makers (plant breeders).
- Sustainability: Diversity at multiple levels leads to a more sustainable agriculture. Genetic diversity, crop diversity, cropping system diversity, farming system diversity, community diversity, and intellectual diversity are needed. The merger-acquisition model of late 20th century economics continues today. Justification for such activity includes efficiency of scale, which by definition works against diversity. As acquisitions occur in the seed industry, large geographical areas are abandoned. Farmers in these regions are left to use old cultivars or ones that were developed elsewhere and just happened to fit their needs. This has negative effects on the future of those farms, thereby decreasing diversity at the level of community. Numerous public breeders working in diverse ecosystems with diverse crops needed to increase diversity at all levels.
- Independence: Ideally, public plant breeders do not have an economic interest in the results of their breeding program. Therefore decisions should be made in the public interest. Public breeders should be able to focus on solutions that do not necessarily result in high seed sales volume, such as long-lived perennials and pure line and open-pollinated cultivars, or in unique and original ideas such as supersweet corn and afila pea.
- Public service: Plant breeders actually developing cultivars adapted to the local environment must be familiar with the needs and challenges of the local farmers and consumers. Academic plant breeders (no cultivar development) can operate independently of the local community responding only to grant and manuscript reviewers.
- Education: Actual cultivar development programs at Universities with complete plant breeding curricula offer the best opportunity for training the next generation of plant breeders. If the next generation is to consist of selectionists then we need to reemphasize the role of population/quantitative thinking as the foundation for the education of plant breeders
- Continuity and efficiency: Successful plant breeding programs require long-term continuity. Plant breeding requires cycles of selection and recombination. Plant breeding, unlike other types of research, cannot be started and stopped based on three year granting cycles. Plant breeding is rapid only when programs are continuous. Plant breeding programs that suffer interruptions are slow and inefficient. If society requires rapid gains,

plant breeding programs require continuous support.

Summary

Plant breeding is a technology that harnesses the creative power of selection. It is powerful, precise, and predictable. Selection and genetic recombination create new organisms. Plant breeders must be concerned with adaptation of new cultivars; however, the area of adaptation is an economic decision. As for many professions it takes many years of experience for a plant breeder to develop the requisite skill (art or eye) to be most effective. While plant breeding (selection) is a useful and efficient technology, the continuation of this discipline is by no means assured. The paradigm for crop improvement has shifted from selection to engineering. It is not clear whether selection can survive the competition from this new paradigm. Even if plant breeding survives as an idea it is unclear that it will survive as a function of the public sector despite clear public benefits. These benefits including food security based on diversity of decision makers, crops, and cropping systems must be demonstrated to stakeholders if plant breeding is to survive. Plant breeding is one of humanities most successful and benign technologies, but its future depends on whether society elects to continue its support.

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What is Animal Breeding?

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Introduction

Throughout the history of agriculture, farmers around the world have dedicated themselves to caring for and breeding domestic animals. Over the centuries they selected those animals from among their stocks that approached a closely held image of success. These efforts created an array of distinct breeds of animals that were maintained and used. (Bixby, et al., p.8; Christman, et al., p.1; Sponenberg and Christman, p.5)

Today, livestock breeders have inherited an extraordinary genetic wealth of distinct breeds. Historically it was certain that every generation of breeders understood its need to provide stewardship for this treasure. Each generation produced changes in the breeds, but a broad package of genetic material would pass from one generation to the next in a range of breeds. This range of breeds represents the genetic diversity within the species. (Sponenberg and Christman, p.1)

Wendell Berry writes in the forward to *A Rare Breeds Album of American Livestock*, “The diversity of livestock breeds and domestic plant varieties can be thought of as a sort of vocabulary with which we may make appropriate responses to the diversity of localities… Every trait and quality of the most out-of-favor breed, having already proved useful somewhere, must be presumed to be potentially useful somewhere.”

Times have changed and the traditions of animal breeders are cast aside by industrialization of agriculture and the urbanization of society. Nearly a third of the breeds found in the United States and globally are threatened by extinction. At the same time, the popular breeds are becoming less distinct as a narrow set of selection criteria is rigidly applied to succeeding generations of livestock. (Sponenberg and Christman, p. 1)

The taxonomic unit of variation in domestic animals is the breed, which coincides roughly with the subspecies in wild animals. A breed is best described by Juliette Clutton-Brock as “a group of animals which may be readily distinguished from other members of the species and which are consistent within a range of parameters: when bred to one another, members of the breed reproduce the distinguishing type.” Breeds are not absolute like species, but dynamic as they adapt to the habitat of the farm. (Bixby, et al., p. 8; Christman, et al., p. 1)

Five Steps to Breed Development

- Breed types were developed with heavy natural selection by geography, climate, and isolation. A useful type is identified in a region. This is the founder effect.
- One or more breeders begin selecting for characteristics and type by linebreeding or inbreeding to concentrate desirable traits.
- The infant breed is composed of the survivors of inbreeding and becomes popularized.
- A herdbook is developed to track pedigrees.
- Breed societies form to control and manage the herdbook and breed standard.

(*http://microvet.arizona.edu/Courses/VSC105/britain.PDF*)

The creation of breeds takes place over a long period of time. Each breed, while containing some diversity within, is uniform and predictable, having a unique combination of genetic traits. Stefan Adalsteinsonn refers to this as the “genetic heritage of survival,” meaning that each breed’s history is embedded in its genetic makeup. (Sponenberg and Christman, p.5) Or in Wendell Berry’s more vernacular style in the earlier citation, “My friend Maurice Telleen pointed out that fifty years ago, the Ayrshire was a popular dairy cow in New England and Kansas because of her ability to make milk on the feed that was locally available. She was a cow that could get along. It is dangerous, I think that we have got beyond the need for farm animals that can get along.”

Types of Breeds

A breed is a group of animals with a consistent array of genetic characteristics. Within the breeds, there are some major types. These major types include landraces, standardized breeds, industrial strains, and feral populations. Each of these reflects differences about the attitude of human caretakers towards the genetic package, and each type has something to teach about breeds, genetic packages, and human endeavor.

Landrace: "Landrace" as used here, is a general term that refers to populations that are isolated to a local area where local production goals and situations drive selection. A landraces represent an early stage of breed development. The "Landrace" designation should not be confused with the Landrace swine breed or the Finnish Landrace sheep breed. The landrace concept is important as a general pattern for many important breeds. Most landraces have had long-term selection and production in compromised environments outside of the agricultural mainstream. Isolation, founders, and selection environment all combine to determine the overall type and function of landraces. An example is the Mulefoot hog, a large black breed with semi-lop ears and fused digits, found in the mid-Mississippi River valley. Isolation for most landraces has been caused by geographic factors. As time passes and development proceeds, the isolation that protected these genetic packages is disappearing. With decreasing isolation and changing selection pressures, the uniqueness of many landraces diminishes, and with their disappearance go many highly adapted genetic resources. (Christman, et al., p.3; Sponenberg and Christman, pp. 6-7)

Standardized breeds: Standardized breeds are populations of animals that are enrolled into a herdbook or studbook. They are selected to conform to a standard that describes the ideal physical (or in some cases behavioral) type of the breed. The existence of the standard gives this group of breeds its name. Most standardized breeds descend from landrace populations. Breeders decide what is included and what is excluded in a standardized breed. Eventually, the population is "closed," that is only offspring of approved parents (generally registered ones) can be registered. As the boundary is drawn around a standardized breed, characteristics and traits are lost, intentionally or unintentionally. As a result, standardized breeds include less variation than do landraces. Berkshire and Yorkshire swine are examples of standardized breeds. (Christman, et al., p.3; Sponenberg and Christman, pp. 8-9)

Industrial strains: Industrial strains are usually not characterized as breeds. In most cases these are standardized breeds or hybrids that are narrowly selected for specific production characteristics in a specific environment that benefits from controlled nutrition, environment, and breeding. The strains are usually given corporate code or brand designations rather than names. Population data has not been available on these strains since they are closely held by the corporations that have developed them. Private breeders are typically not involved, and so the documentation of registrations and the like has become superfluous for industrial strains. (Christman, et al., p.3)

Feral animals: Feral animals are domesticated animals that have returned to a free-living state. It is a peculiar fact of biology that the truly wild type and wild genetic strain are never again fully regained, though some feral animals do indeed approach the wild type. Feral animals are interesting because they have returned to a selection environment where nature rather than humans decide which ones reproduce and which ones succumb. Some feral populations are genetically distinct and usually come from a few founders. Others have much broader genetic variation due to constant infusion of new recruits from a wide variety of genetic sources. Ossabaw Island swine is one of a very few feral populations that qualify as breeds, because of their long-term environmental adaptation genetic isolation. (Bixby et al., p.147; Christman, et al., p.3; Sponenberg and Christman, pp. 9-10)

Concept and Practice of Selection

All breeds have been developed, and are continually shaped through the process of selection based on fitness or preference. For poultry and livestock, selection results in the survival and propagation of some individuals but not others with the result that inherited traits of the survivors are perpetuated. Selection is at work any time that animals in a group do not contribute equally to the genetic pool of the next generation. Selection influences the genetic variation found in populations. Most characteristics will have many possible expressions. Since selection favors some of these and penalizes others, the direction of the population is determined as the population becomes more uniform. Domestic breeds have been shaped by both natural and human selection. Natural selection favors survival. Human selection is much more recent and favors production, sometimes at the expense of biological fitness.

Selection has both positive and the negative aspects. Positive selection is the choice of animals for reproduction. Negative selecting is the choice against the use of animals for reproduction. Selection is usually directed at a few specific characteristics, but selection acts on the entire animal. All of its genetic traits (whether under selection not) are either perpetuated or lost. (Sponenberg and Christman, pp.18-19)

Breeding Systems

Inbreeding

Inbreeding is the mating of animals that are related so that the resulting offspring have one or more ancestors in common on both sides of their pedigree. Close inbreeding involves closely related animals such as full siblings or parent and offspring. Distant inbreeding would involve half siblings or cousin to cousin. Inbreeding is a powerful method for intensifying genetic characteristics and revealing recessive traits. Some of these traits are desirable while others are not. Culling is an important aspect of successful inbreeding. (Sponenberg and Christman, pp. 25-6)

Linebreeding

Linebreeding is a form of inbreeding with the goal of concentrating desirable characteristics from a single individual throughout the population. The most common mating is a half brother to a half sister. Cousin matings are also considered Linebreeding, as is the use of an outstanding individual in several generations. The difference between linebreeding and inbreeding is subtle. This method has been used to develop standardized breeds such as the Morgan horse, and also the development of bloodlines or strains within breeds.

The strengths of inbreeding and linebreeding are that they narrow the range of variation, making the resulting population more uniform and predictable. The disadvantages include the possible loss of vigor and reproductive performance as well as unrecognized genetic erosion. (Sponenberg and Christman, pp. 25-7)

Linecrossing

Bloodlines or strains are sub-breed groups that are more closely related to one another than they are to the breed as a whole. Linecrossing is the mating of individuals of different bloodlines. Linecrossing is similar to cross breeding in that it will generate hybrid vigor or a performance boost in the first generation. Linecrossing is often used to produce outstanding individuals for production or show stock. Linecrossing can also be used from time to time to increase vigor in linebred populations from different bloodlines. (Sponenberg and Christman, pp. 27-8)

Crossbreeding

Crossbreeding refers to mating individuals of two different breeds. This can be an interesting and productive endeavor. The first generation of a cross two distantly related breeds usually exhibits a spectacular performance boost known as hybrid vigor or heterosis.

Most livestock industries rely on this phenomenon to get superior production stock. An example is the “black baldie” resulting from the crossing of Angus and Hereford cattle. Black baldies are black with white faces. If they are bred to each other, however, the results are unpredictable: solid black cattle, solid red cattle, white-faced blacks, white-faced reds, horn on some, others polled. While production characteristics are not visible, they generally follow the same patterns of inheritance.

The initial uniformity results from the uniformity of the parents. For every gene site there is a gene contributed by the Angus and one contributed by the Hereford. The next generation’s variability results for the re-segregation of pairs. While in theory it would be possible to reassemble a purebred Angus or Hereford from the mix, this is practically impossible.

Though crossbreeding is a one-way street away from purebred parent stock, the resulting genetics can be used to develop new breeds. Breed crossing in the mid to late 1800s was the basis for almost all poultry breeds developed in America. The familiar Barred Plymouth Rock was developed from the Dominique, Java, and other breeds. The successful Katahdin sheep breed was developed only about 50 years ago from Wiltshire Horned, St. Croix, and Suffolk genetics. The Polypay sheep gets it name and hardiness from the many breeds contributing genetics to its development.

Success in crossbreeding is dependent on maintaining purebred, genetically distinct parent stock. Unfortunately we see the genetic selection of breeds becoming similar to each other. Examples are the black-faced sheep breeds, and the ever-leaner swine breeds. The performance boost expected from crossing these similar breeds is reduced because of the loss of genetic distinctiveness.

Many uncommon breeds offer great performance boosts in crossbreeding. Males of these breeds can be bred to females of common breeds to produce offspring that combine performance with soundness. Dutch Belted bulls are often bred to Holstein cows, and Cleveland Bay stallions to Thoroughbred mares. The goal is to produce offspring marked by hybrid vigor and a useful combination of the parents' characteristics. Crossbreeding rare breed females is a waste of their genetic value. While crossing of Cleveland Bay mares with Thoroughbred stallions, and Texas Longhorns to improved beef bulls has produced many desirable production animals, crossbreeding has hastened the demise of purebred stock that is necessary to produce the crossbreds. This is much like killing the goose that lays the golden eggs. (Sponenberg and Christman, pp. 28-9)

Random Breeding and Multi Sire Mating

Random breeding and multi-sire mating are management techniques independent of breed system. Random breeding means that the replacement animals are selected and pair mated without regard to appearance or performance. Random breeding is usually assumed to be operational in populations studied by theoretical geneticists in the exploration of population size on genetic structure.

Multi-sire mating means that many sires are allowed to run with a group of females and there is no direct control over specific matings. Multi-sire matings differ from random breeding in two ways. First, the group of males chosen has generally been selected from a larger group of males that were considered as potential sires. Second is that if all the males are used at the same time in a breeding group the result will likely be that the socially dominant male will sire the most offspring, while the more submissive males have fewer or no offspring. Multi-sire mating is common in poultry and will often succeed if care is taken to assure a relatively broad genetic contribution from a number of males representing different strains, not just a single dominate male. This system is appropriate for primitive adapted breeds and landraces since it provides for some continued selection based on environmental adaptation and social interactions. (Sponenberg and Christman, pp. 30-1)

Genetic Diversity

Human selection causes genetic variation in domesticated animals that is different than in wild animals. Even the term "species" is somewhat awkward when applied to domesticated animals, since most livestock species have had inputs from more than one ancestral species, most of whom are now extinct. As the only living representatives of some of these lineages, domesticated animals are a critical component of the overall biodiversity of the planet. It also means that animal scientists cannot go to the wild variants for genetic infusions as plant scientists do.

It is important to realize that more than external physical qualities define a breed. Each breed is also defined by specific, complex behaviors and other heritable traits. All of these are not easily attributed to specific, identifiable genes. Rather, they are the result of unique gene configurations and combinations developed through generations of reproductive isolation. Formal development of breeds and application of the breed concept is a recent phenomenon and primarily a product of western culture.

Since livestock breeds were developed to be different from one another and have been maintained in isolation from one another, they are identifiable packages of distinct genetic content and configuration. The number of breeds and the numbers of animals within the breeds are good indicators of the status of genetic diversity within each livestock species. (Bixby et al., pp. 8-9)

Conservation Programs

The American Livestock Breeds Conservancy (ALBC) is the pioneer livestock conservation organization in North America. Incorporated in 1977, the ALBC is a nonprofit membership agency dedicated to protecting the genetic diversity in American livestock and poultry through the conservation of over 100 breeds of cattle, donkeys, goats, horses, sheep, swine, chickens, ducks, geese, and turkeys.

The American Livestock Breeds Conservancy was founded by agricultural historians, seeking historically authentic livestock for interpretive programs at Old Sturbridge Village and other historic sites. They discovered that many of these breeds were nearly extinct. The historians were joined by a diverse group of animal scientists, farmers, educators, academics, and people who understood the cultural and genetic value of breeds. ALBC programs include monitoring breed populations, research, education and direct conservation of rare livestock and poultry breeds.

The first step in conservation is determining what is to be conserved. On-going censusing by ALBC confirms the position of United Nations Food and Agriculture Organization that one third of livestock breeds are threatened with extinction. ALBC research of breed status and characteristics also determines conservation priorities. One of the tools that result from the ALBC population research is the ALBC Conservation Priority List. Breeds are assigned to a category according to their degree of endangerment. Over 100 breeds are listed on the Conservation Priority List. (See Table 1)

Programs include the operation of a gene bank; blood-typing and DNA analyses for breed characterization; rescues of threatened populations; and the development of genetic recovery breeding protocols

Education is the key to successful conservation. . ALBC educates the public and policy makers about the importance of conserving genetic resources and provides technical support for breeding, registry operation, and livestock use for individual, breed associations, and agricultural organizations.

Technical support to breeders and promotional materials are made available through the ALBC web site, the bimonthly *ALBC News*, position papers and publications, and workshops, as well as collaborations with a range of organization working in sustainable agriculture, ecology, and education about the natural and cultural world of humans and farm animals. An important goal of education is the promotion of selection of appropriate genetics for non-conventional and sustainable production systems. (Christman et al, p. 108; www.albc-usa.org)

Direct conservation includes the occasional rescue or relocation of important genetic populations. For long-tem conservation, gene banking is a critical project to safeguard current genetics and extend the genetic pool of the future. ALBC established a gene bank in 1986, beginning with the Milking Devon cattle breed. The collection now includes 17 of the rarest breeds, including 12 breeds of cattle, three breeds of swine, one breed of sheep and one breed of goats.

After years of discussion between ALBC and government officials and a congressional mandate in the 1990 Farm Bill, the USDA established an animal gene bank headquartered in Fort Collins, Colorado. This facility is an expansion and reorganization of the National Seed Stock Laboratory established there in 1956 to collect and protect plant genetic materials. ALBC sits on the Policy Coordination committee, which is made of each of the chairs of the species committees: beef, dairy, small ruminants, poultry, aquaculture, as well as the technical committee. The three areas of activity for the gene bank include the accession of a diverse collection of genetic materials from livestock and poultry breeds; genetic characterization of breeds; and generating data for the breed profiles of the USDA Genetic Resources Information Network (GRIN) (*www.albc-usa.org*)

History of livestock breeding

A quick review of the history of livestock breeding will be illustrative of what has been done, and what we might hope for the future of animal breeding.

Breed types have existed for millennia, due largely to geographic isolation. Selective breeding for fixed types only began in the 1500s and 1600s. Breeds that resulted from early selection include Spanish horses, Merino sheep, and Devon cattle. Henry VIII fostered horse improvement in the 1500s by decreeing a minimum height for all breeding stallions. That decree was instrumental in developing the English Thoroughbred.

After the strife and civil war in England during the 17th century, the 18th century provided a more settled background for both an agricultural and industrial revolution as people left the farms and fields for the mills and factories. During the reign of George III, the Parliamentary Act of enclosure enclosed nearly six million acres of manorial land. Better control of livestock, which no longer roamed at will on common land, provided an opportunity to initiate selective breed. (Pawson, p. 5)

By the late 1700s breeders developed a better understanding of reproduction and transmission of characteristics from generation to generation. Robert Bakewell, a farmer from the midlands of England, set the pattern for modern livestock breeding with heavy selection and documentation of pedigrees. His focus was the intense inbreeding of English Longhorn cattle, Leicester sheep, Shire horses, and Progeny testing of sires. Bakewell's work became the model for other stock breeders. (*http://microvet.arizona.edu/Courses/VSC105/britain.PDF*)

In 1783 Bakewell organized the Dishley Society, essentially the first breed association, to control the selection of improved breeds. The Thoroughbred Studbook was published in 1791, and the Coates Herdbook for Shorthorn cattle was published in 1822. The Shorthorn cattle breed eventually eclipsed the Longhorns in popularity and became the first international breed, a distinction the breed held until well into the 20th century. (Wood and Orel, p. 117)

Bakewell's successful livestock improvement was adopted in continental Europe as well. The results were especially noteworthy under the guidance of Baron Ferdinand Geisslern, in Moravia, part of the Hapsburg Empire. Geisslern applied Bakewell's precepts to the imported Merino sheep on his estate to improve fine-wool production. His success inspired other commercial breeding projects, the most successful of which were the improving fruit trees and vines.

In this connection, important work was carried out by members of the monastic community of St. Thomas in Brno, a tradition that would eventually encompass the work of Gregor Mendal. While there is no direct connection between sheep breeding and Mendel's work, the search for rules of heredity in sheep created an atmosphere of enquiry about heredity in general; that one of the major locations where the search took place was in Brno; and that certain public figures that Mendel respected were deeply committed to the search. (Wood and Orel, p vii-ix) Medal, an Austrian abbot, experimented with plant inbreeding of the closest kind, the self-pollinating pea. His work gave us the Mendalian law of inheritance that was published in 1865. (Pawson, p. xiii)

Throughout the 1800s there was increasing interest in improving American farm stock by the importation of pedigreed stock, especially Shorthorn and Channel Islands breeds of cattle such as Alderney, Jersey, and Guernsey, and improved breeds of sheep such as the Bakewell (or Leicester) breeds, Cotswold, and others. In the late 1800s, many breed associations were formed for livestock, and American Poultry Association published its first *Standard of Excellence* establishing the standards for poultry breeds. As breeds became standardized, a huge number of regional swine breeds became consolidated. In 1883, the establishment of the American Duroc-Jersey Record Association incorporated many breeds of red hogs. (Evans, p.17)

Livestock Breeding in the 20th Century

There was a spate of breed development in the first half of the 20th century. Minnesota Agricultural Experimental Station produced the Minnesota No. 1 pig in 1936-40. The breed arose from the genetics of the Tamworth and Danish Landrace. Minnesota No. 2 was developed in 1941-8 from Yorkshire and Poland China breeds. (Mason, 1996, p. 170) The Montana No.1 pig, also known as Black Hamprace, was developed between 1936-48 from Landrace and Hampshire crossings at Miles City, Montana. (Mason, p. 171) While all three breeds developed a devoted following of producers, they have all since disappeared.

To meet the environmental challenges of Texas, two successful breeds of cattle were developed from existing breeds of two species – Bos taurus and Bos indicus. The King Ranch developed the Santa Gertrudis between 1910-40. Stabilized at 5/8 Shorthorn and 3/8 Brahman, Santa Gertrudis became an international breed. (Mason, p. 75). The Beef Master came from the Lassiter Ranch in Texas from Hereford, Shorthorn, and Brahman parentage in the late 1950s. (Mason, p. 21) The Senepol emerged as a successful tropical beef breed in St. Croix, US Virgin Islands between 1918-49 from Red Poll and N'dama breeds at Nelthropp Ranch. (Mason, p. 76)

Katahdin sheep were created in response to the need for a sheep that would concentrate its resources developing a meat carcass without diverting energy to wool production. The Katahdin was developed from Suffolk, Wiltshire Horn, and Virgin Island Whites seep at the Piel farm in Maine in 1957. (Mason, p.222)

The US Sheep Experimental Station at Dubois, Idaho, gave us the Polypay breed in 1969. The Polypay gains its strength from the genetic diversity provided by Rambouillet, Lincoln, Corriedale, Targhee, Dorset, and Finn Sheep. (Mason, p. 241)

The Beltsville Small White turkey was developed by the USDA research center in Beltsville, Maryland, between 1934 and 1941. The goal was to produce a small white turkey for home consumption. The height of its popularity came in the mid-1950s when an estimated 19 million were raised. It was replaced by the Large White, slaughtered at an early age. Today only a research flock remains at Ames, Iowa. (Christman and Hawes, p. 33)

The Beltsville Large White turkey was developed at the same USDA research center in the 1950s-60s, and has come to dominate the industry. Successful selection brought white feathers, more white breast meat, shorter legs, rapid maturation, and feed efficiency. But that narrow selection for production characteristics brought biological unfitness. Low fertility and failing immune, skeletal, and vascular systems now plague the birds. (Christman and Hawes, pp. 22-24)

Though Holstein dairy cattle have been brought to the peak of market expectation, the breed is in serious trouble. In private conversation, Bill Heffernan, University of Missouri Rural Sociologist exploring agricultural consolidation, points to Holstein Association data, that because of low fertility (2.7 services per conception), short production life (1.9 years [two calves, half female]), and offspring mortality at 15%, the diary herd cannot replace itself. And in another private conversation, Les Hansen of University of Minnesota suggested that genetics from other European dairy breeds would need to be imported in increase the fertility of the American Holstein breed.

What is needed?

Holstein cattle and Large White turkeys are selection successes that went too far. Every segment of the livestock industry must incorporate the need to conserve the genetics of their species. They must do this not only for current production, but also for their unknown needs of tomorrow. The industry needs a better understanding of current genetics in order to utilize them for the development of biologically fit livestock. Biologically fit livestock will provide optimum production, not maximum production. In other words, we must conserve and develop livestock than can "get along."

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Conservation Priority Livestock Breeds 2003

Critical: Fewer than 200 annual North American registrations and estimated fewer than 2,000 global population

Rare: Fewer than 1,000 annual North American registrations and estimated fewer than 5,000 global population.

Watch: Fewer than 2,500 annual North American registrations and estimated fewer than 10,000 global population. Also included are breeds with genetic or numerical concerns or have a limited geographic distribution.

Study: Breeds that are of interest but either lack definition or lack genetic or historic documentation.

Recovering: Breeds which were once listed in one of the other categories and have exceeded Watch category numbers but are still in need of monitoring.

	Critical	Rare	Watch	Study	Recovering
Asses	Poitou	[1] **American Mammoth Jackstock**			Miniature Donkey
Cattle	Beef Devon [1] **Canadienne** Dutch Belted [1] **Florida Cracker** Kerry [1] **Milking Devon** [1] **Pineywoods** [1] **Randall Lineback** White Park	Ankole-Watusi Dexter Red Poll	Ayrshire Belted Galloway Galloway Guernsey Milking Shorthorn		Highland
Goats	[1] **San Clemente** (F)	[1] **Tennessee Fainting**	[1] **Nigerian Dwarf** Oberhasli [1] **Spanish**		
Horses	Akhal-Teke [1] **American Cream** Caspian Cleveland Bay Exmoor [1] **Florida Cracker** [1] **Mountain Pleasure** [1] **Spanish Mustang/ Spanish Barb** (F) Suffolk	[1] **Canadian** Dartmoor Fell Pony Hackney Horse Lipizzan [1] **Rocky Mountai**n	Clydesdale Friesian Gotland Shire	Dales Pony Irish Draught	Belgian Percheron
Pigs	Gloucestershire Old Spots [1] **Guinea Hog** Large Black [1] **Mulefoot** [1] **Ossabaw Island** (F) [1] **Red Wattle** Saddleback	[1] **Hereford** Tamworth		[1] **Choctaw**	
Sheep	[1] **California Variegated Mutant/Romeldale** [1] **Gulf Coast Native** [1] **Hog Island** (F) [1] **Santa Cruz** (F)	Cotswold [1] **Jacob (American)** [1] **Karakul (American)** Leicester Longwool [1] **Navajo-Churro** [1] **St. Croix** [1] **Tunis** Wiltshire Horn	[1] **Barbados Blackbelly** Dorset Horn Lincoln Oxford	[2] Soay	Black Welsh Mountain Clun Forest [1] **Katahdin** Shetland Shropshire Southdown

[1] **Originated in North America** [2] British registered (F) Feral populations or breed of feral origin

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The American Livestock Breeds Conservancy

Conservation Priority Poultry Breeds 2003

Critical: Fewer than 500 breeding birds in North America, with five or fewer primary breeding flocks (50 birds or more).

Rare: Fewer than 1,000 breeding birds in North America, with seven or fewer primary breeding flocks.

Watch: Fewer than 5,000 breeding birds in North America, with ten or fewer primary breeding flocks. Also included are breeds which present genetic or numerical concerns or have a limited geographic distribution.

Study: Breeds which are of interest but either lack definition or lack genetic or historical documentation.

Recovering: Breeds which were once listed in one of the other categories and have exceeded Watch category numbers but are still in need of monitoring.

	Critical	Rare	Watch	Study	Recovering
Chickens	Andalusian Aseel [1] **Buckeye** Buttercup Campine Catalana [1] **Chantecler** Crevecoeur [1] **Delaware** Dorking [1] **Holland** Houdan [1] **Java** Malay Spanish	Ancona Lakenvelder Langshan Sussex	Brahma Cochin Cornish - Non-industrial [1] **Dominique** Hamburg [1] **Jersey Giant** Leghorn - Non industrial Minorca [1] **New Hampshire** Polish [1] **Rhode Island White**	[2] Araucana [1] **Cubalaya** Egyptian Fayoumis Faverolle Hungarian Yellow [1] **Iowa Blue** La Fleche [1,3] **Lamona** Modern Game Nankin Old English Game Redcap Russian Orloff Sebright Shamo Sultan Sumatra	Australorp Orpington [1] **Plymouth Rock - Non-industrial** [1] **Rhode Island Red** [1] **Wyandotte**
Ducks	Ancona Aylesbury Magpie Saxony Silver Appleyard Welsh Harlequin	Buff (a.k.a. Orpington) [1] **Cayuga**	Campbell [4] Rouen Runner (a.k.a. Indian Runner) Swedish	[1] **Australian Spotted**	
Geese	[1] **American Buff** [1] **Pilgrim** Pomeranian Roman	Sebastopol	[5] African Chinese [6] Toulouse	Shetland Gray	
Turkeys	[1] **Beltsville Small White** Black [1] **Jersey Buff** [1] **Narragansett** Slate [1] **Standard Bronz**e White Holland [1] **White Midget**	[1] **Royal Palm**	[1] **Bourbon Red**	[1] **Broad Breasted Bronze** Other varieties of naturally mating turkeys	

[1] **Originated in North America**
[2] Araucanas and Ameraucanas are often confused with each other, and may be sold interchangeably.
[3] May be extinct.
[4] Rouen: There are two distinct types: the production bird and the larger exhibition bird.
[5] African: The large, dewlapped bird reflects the original phenotype, is an exceptional meat bird and is of conservation interest. The smaller African goose likely contains some influence of the Chinese goose, a relative of the African.
[6] Toulouse: There are three distinct types. All are of conservation interest. The standard Toulouse, a large, dewlapped bird with elongated feathers, loose skin, and a keel, is a good layer and is a unique color of grey. The smaller Toulouse is a longer legged, tightly feathered, keel-less goose with no dewlap. The exhibition Toulouse has an exaggerated dewlap.

Return to Resistance: Breeding Crops to Reduce Pesticide Dependency

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Horizontal Resistance

Single-gene resistances (vertical resistances) have been the resistance of choice among plant breeders for the past century. These resistances are qualitative in the sense that they are either present or absent, with no intermediates. This means that they either provide a complete protection or none at all. These vertical resistances have many advantages but they also have one grave disadvantage in that they are liable to break down to new races of the pest or disease. Typically, they provide protection that is complete, but temporary.

Many-gene resistances (horizontal resistances) have been largely ignored by plant breeders during the past century. They have the great advantage that they do not break down like vertical resistance. They provide a durable resistance. They are also quantitative in the sense that they can exhibit every difference in degree between a minimum and a maximum. In the absence of crop protection chemicals, the minimum level of horizontal resistance usually leads to a complete loss of crop from the parasite, while the maximum level of horizontal resistance leads to a negligible loss of crop. Consequently, horizontal resistance provides a protection which is permanent, but which may not be complete.

A feature of quantitative resistance is that different levels of resistance will be required in different agro-ecosystems. This is because the epidemiological competence of most crop parasites varies widely from one agro-ecosystem to another. A cultivar that is in perfect balance with one agro-ecosystem will have too much resistance to some parasites, and too little to others, when taken to a different agro-ecosystem. Consequently, when using horizontal resistance, each major agro-ecosystem should have its own breeding program for each species of crop. This is in sharp contrast to vertical resistance, which permits the use of a single cultivar over a very wide geographical range.

Difficulties

It should be remembered that three generations of professional plant breeders have now been working almost exclusively with single-gene resistances. This tradition has been strongly reinforced by the growth of molecular biology which, of necessity, can only involve single genes. Consequently, many professional breeders are reluctant to acknowledge that horizontal resistance may provide a superior alternative to single-gene resistances.

It should also be remembered that horizontal resistance tends to be lost during breeding for vertical resistance, or when breeding under the protection of pesticides. This is known as the vertifolia effect. It is at its greatest in crops such as potatoes, tomatoes, and cotton. Many crops have been losing horizontal resistance in this way for a century or more, and their modern cultivars are consequently very susceptible to pests and diseases. This is the reason for our massive use of crop protection chemicals, and it is a key difference between corporate and private plant breeding. As a general rule, corporate breeders, with their agro-chemical interests, prefer susceptibility and a high consumption of pesticides. Private breeders usually prefer resistance and a low consumption of pesticides.

Plant Breeding Clubs

There were no professional plant breeders before 1900. All plant breeding was undertaken by farmers and other amateur breeders. And these amateurs were working with quantitative variables such as horizontal resistance. Professional plant breeding began with the recognition of Mendel’s laws of inheritance in 1900, and it emphasized single-gene characters, such as vertical resistance. This kind of plant breeding is highly technical and expensive, and it produces relatively few cultivars.

Breeding for horizontal resistance is easy in most species of crop, given a modest knowledge of quantitative genetics. It can be undertaken by amateur breeders, such as farmers, hobby gardeners, environmentalists, green activists, university students, and even school children. Although some individuals may prefer to work on their own, the most effective amateur breeding is likely to be achieved by plant breeding clubs. Groups of such amateurs assisted, no doubt, by sympathetic scientists, can breed crops cooperatively within a plant breeding club. The most successful breeding clubs are likely to be university clubs, because of the university ambience, student enthusiasm, and the availability of technical assistance.

If we are to utilize horizontal resistance, the need for cultivars to be in balance with the local agro-ecosystem, and the vertifolia effect, must both be taken into account. This will require a very large amount of horizontal resistance breeding. This is because of the fact that a separate breeding program will be needed for each species of crop in each major agro-ecosystem, and because of existing susceptibilities due to the vertifolia effect. Indeed, the total horizontal resistance breeding is probably far beyond the scope of the existing corps of professional breeders, even if they were willing to switch techniques. It seems we must depend on amateur breeders, if this huge task is to be undertaken at all, and if it is to be completed in a reasonable time.

One of the many advantages of durable resistance is that a good cultivar need never be replaced, except with a better cultivar. Breeding for horizontal resistance is cumulative and progressive. It can continue until a ceiling of excellence is reached, and then no further improvement is possible. These improvements will lead to maximum levels of horizontal resistance to all locally important parasites, maximum yield, excellent quality of crop product, and excellent agronomic suitability. Each farmer in each agro-ecosystem will then have a choice of superlative cultivars that meet all of his requirements.

When a few plant breeders, working with vertical resistance, control the cultivars available to very many farmers throughout a large region, the breeding may be described as autocratic. Many farmers then have little or no choice of cultivars. But when there are very many plant breeding clubs, often made up of the farmers themselves, and working with horizontal resistance, the breeding becomes democratic. Farmers have a very wide choice of cultivars. The eventual effects of democratic plant breeding would be maximum improvements in all cultivar qualities; major reductions in the use of pesticides; major increases in total production and biodiversity; and an improved stability of production. And these effects will occur in every agro-ecosystem whose inhabitants embrace the idea of plant breeding clubs that employ horizontal resistance.

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Keynote 1

Responses

Keynote 1: What would 21st Century Breeding Programs Look Like if They Were Geared Toward a More Sustainable Agriculture-Objectives, Goals.

New Seeds and Breeds for a New Revolution in Agriculture[1]

Frederick Kirschenmann

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> *Sustainable and productive ecosystems have tight internal cycling of nutrients, a lesson that agriculture must relearn. . . a greener revolution is also needed---a revolution that incorporates accumulated knowledge of ecological processes and feedbacks, disease dynamics, soil processes and microbial ecology.*
>
> ---David Tilman, 1998

> *The real problem of food production occurs within a complex, mutually influential relationship of soil, plants, animals, and people. A real solution to that problem will therefore be ecologically, agriculturally, and culturally healthful . . . a bad solution solves for a single purpose or goal, such as increased production. And it is typical of such solutions that they achieve stupendous increases in production at exorbitant biological and social costs.*
>
> ---Wendell Berry, 1980

> *We need to study these organisms under natural conditions much more than we have in the past in order to secure an adequate fund of basic information to use in planning improved relationships of people to the land.*
>
> ---Herbert C. Hanson, 1939

As we enter the 21st century we face at least seven major challenges that will threaten the sustainability of industrial agriculture. Population growth, persistent poverty, energy needs, environmental degradation, food security, climate change, and an unprecedented explosion of infectious diseases—all seven developments likely will force us to rethink the assumptions about food and agriculture that we have taken for granted for at least 50 years.

The United Nations estimates that by the year 2050, the world's current population of more than 6 billion people will increase to 9.3 billion. Furthermore, the additional 3.2 billion people will be added in the developing world (some of that perhaps adjusted for migration) and much of that growth will take place in poor rural areas. Seventy-two percent of the world's poorest people now live in rural communities.[2]

Currently, 1 billion of the world's population lives on less than $1 a day and an additional 1.6 billion live on less than $2 a day. The number of people living in poverty has increased by 100 million during the past decade and the United Nations predicts that another 100 million people will live in poverty by the year 2015.[3]

While dramatic population growth and persistent poverty overtake us, the natural resources that have fueled the production increases of the past 50 years are in a state of decline. Industrialized agriculture—which enabled us to double and triple the yields of a few cereal grains—is largely fossil fuel driven. Crop inputs, the manufacture of farm equipment, tractor fuel, and the breeding of crop varieties that are responsive to chemical inputs and irrigation are all highly dependent on fossil fuel energy. As fossil fuel resources decline, and therefore become more costly, this mode of production will become increasingly difficult.

At the same time that the natural resources that fueled industrial agriculture are declining, the natural sinks that absorbed the accompanying agricultural wastes are filling up. Worldwide there are at least 50 hypoxic zones on the planet,[4] all of them related to watersheds that support industrial agriculture. And hypoxic zones are not isolated aberrations but visible indicators of the larger environmental deterioration that is inherent in industrial agriculture systems.

Masae Shiyomi and Hiroshi Koizumi, in fact, have argued that the combination of the decline of fossil fuels, and the increased environmental degradation caused, in part, by fossil fuel-based agriculture, will necessarily *force* agriculture to change in the decades ahead, and they suggest that a shift toward an ecologically-based agriculture may well pose the most viable alternative for agriculture's future.

> The present system of agriculture, which depends on consumption of tremendous quantities of fossil fuel energy, is now being forced to change to a system where the interactions between organisms and the environment are properly used. There are two reasons for this transformation. The first is the depletion of readily available fossil fuel resources. The second is that consumption of fossil fuels has induced deterioration of the environment . . . Is it possible to replace current technologies based on fossil energy with proper interactions operating between crops/livestock and other organisms to enhance agricultural production? If the answer is yes, then modern agriculture, which uses only the simplest biotic responses, can be transformed into an alternative system of agriculture, in which the use of complex biotic interactions becomes the key technology.[5]

A fifth challenge facing agriculture is the increased recognition of food security as a basic human right. Not only is the world evolving into a global economy, it also is becoming a global civic society. Such a society carries with it a greater awareness that a stable global community can be achieved only if all its inhabitants are fed properly. Securing food as a basic right for all of the planet's citizens therefore presents an additional challenge that global agriculture must face in the decades ahead.

The precise role that climate change will play in agriculture's future is not yet certain, but indicators suggest some formidable challenges. A recent report from the Soil and Water Conservation Society focused on just one climactic variable—precipitation —and assessed the potential effects which increased precipitation may have on soil erosion and nutrient runoff from cropland. The study concludes that anticipated rises in precipitation due to climate change, together with the likelihood of more violent storms, "heightens the risk of soil erosion, runoff, and related environmental and ecological damages."[6]

A recent Iowa State University study reveals similar concerns. Using computer-modeling technology, the study found that the Upper Mississippi River Basin (UMRB) is likely to see significant precipitation increases by the decade of 2040-2050. The study reported that the "model system produced an increase in future scenario climate precipitation of 21 percent with a resulting 18 percent increase in snowfall, 51 percent increase in surface runoff, 43 percent increase in recharge and 50 percent increase in total water yield in the UMRB."[7] It is unlikely that Iowans will be able to continue growing massive quantities of annual crops such as corn and soybeans under these circumstances.

Finally, the fact that an unprecedented explosion of more than 35 new infectious diseases has appeared in the past 30 years presents agriculture with yet another challenge. The Institute of Medicine, a research arm of the federal government, recently convened a panel of scientists to determine why this outbreak of infectious disease has taken place. They attributed the phenomenon to 13 changes and Dr. Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases pointed out that a substantial proportion of those changes "relate to man's manipulation of ecology."[8] Agriculture, of course, has been a major contributor to such ecological manipulations.

The Role of Seeds and Breeds

All of these situations confronting us as we enter the 21st century pose special challenges for agriculture. What kind of agriculture can meet the requirements of an exploding human population in the face of entrenched poverty in a post-fossil fuel era that must restore the ecological health of the natural resources on which agriculture depends, while the climate is changing, global society insists that food is a human right, and increased infectious diseases require that we attend to the ecological ramifications of human activities?

And a question for this conference might be whether or not the plant seeds and animal breeds that we have developed during the past fifty years—and continue to develop today—will be compatible with the agriculture we must develop to meet the new and vexing challenges of this century?

The many complications involved in meeting these challenges are, by now, readily apparent. Simply increasing food production, we know full well, will not solve the problem of hunger. If that were the case there would *be* no hunger today since we already produce enough food to provide the necessary calories for every person on the planet. Nor is the problem simply a matter of "distribution" as is sometimes suggested. The complexities of hunger and famine in Africa are poignantly illustrated in Barry Bearak's Sunday *New York Times Magazine* article, "Why People Still Starve."[9]

Near the end of his article Bearak sums up the thorny nature of the problem:

> Africa's problems are immense and confounding: paralyzing debt, sorry infrastructure, depleted soil, meager exports, bad government and ethnic and tribal warfare. [He might have added government subsidies in the industrial nations, which keep world commodity prices paid to farmers well below the cost of production.] The majority of Africa's poorest countries have average incomes below the level of Western

> Europe at the start of the 17th century . . . Unlike the days when structural adjustments were seen as direct routes to poverty reduction, now there seems to be little consensus on what to try next. Proposals tend to be modest . . . soil renourishment, manufacturing schemes, public-service jobs, small-scale irrigation . . . "Niche Markets" . . . in the meantime, even if poverty and hunger seem unconquerable, famine surely can be overcome. Only our indifference—only our neglect—allows it to persevere.[10]

Inventing a new technology or producing yet another higher-yielding seed will not "solve" the problem of hunger in Africa. And even if we were able to invent technologies that could put food into every newborn's mouth, how do we address the problem of providing sufficient quantities of fresh water to support an exploding population, especially when the input-dependent agriculture we have developed currently uses 70 percent of the planet's fresh water resources? And how do we sufficiently shrink the ecological footprint of each global citizen to prevent the further destruction of biodiversity so essential to the ecological health of global ecosystems? In his recent book, *Our Final Hour*, Martin Rees, Royal Society Professor at Cambridge University, suggests that the planet could not sustain even our *present* population if everyone consumed as much as middle-class Europeans and North Americans.[11]

Since populations are exploding primarily in poverty-ridden rural areas of the developing world where farmers live on fragile lands, the invention of new technologies which most farmers cannot afford—and that do little to address the ecological problems where they live—will not be instrumental in solving the problem. At the very least we have to approach the problem in light of the local ecology and culture. As Jeffrey McNeely and Sara Scherr point out,

> . . . [if] food is to be accessible to the rural poor, then much of it must be produced where they live, and in ways that increase both their consumption and income. Yet food-producing systems throughout the world are already stressed by eroding soils, declining freshwater reserves, declining fish populations, deforestation, desertification, natural disasters, and global climate change. These and various other factors are making it increasingly difficult to maintain, much less increase, food production in many areas of the world.[12]

Continuing to develop new seeds or breeds designed merely to increase the yields of a few crops under ideal conditions—assuming such additional yield increases are even possible—is not likely to address the multifaceted set of circumstances that contribute to global hunger and famine.

The problem is far too complex to expect that a solution can be reached by introducing a few new technologies to increase the yields of a handful of crops or a few select animal breeds. At the very least, we must address the difficult problem of access for the poor---access to land, credit and markets. And we should stop misleading the public into believing that the problem *can* be solved with simple technological innovations—leaving the majority of us to believe that we have no responsibility for the problem, thereby justifying our indifference and neglect. Misrepresenting the solution to the problem of hunger as a simple matter of inventing yet another new technology is immoral, even by the most rudimentary ethical standards of any civic society. We should end such deceptive rhetoric everywhere—*now*!

The point here is that most of the challenges facing agriculture in this century are part of a complex web of social, political, cultural and biophysical problems that cannot be remedied simply by introducing a new technology into the mix.

Does this mean that technology has no role to play in meeting agriculture's future challenges? Of course not.

The question we face as we attempt to meet these challenges is **not** whether we will use technology to help shape the new agriculture required to meet future challenges. Clearly we will. Nor is the pertinent question what **kind** of technology we will use. We likely will use all available technologies that show any promise of developing an agriculture capable of meeting these challenges. The more important question is **how** we will use the technologies available to us. And one of the questions for this conference is; what kind of seeds and breeds will function optimally in the new diversified plant and animal production systems we must design to meet the new challenges? And a related question is—who will develop them?

To determine how best to use technology to meet the new challenges facing agriculture—and therefore what kinds of seeds and breeds we need—it might be useful to reassess the way we *currently* use technology in agriculture.

Throughout most of the industrial era we have tended to use technologies almost exclusively to perform one-dimensional, single-tactic tasks. We developed and applied pesticides to control a target pest. We manufactured and applied fertilizers to replace nutrients. We produced and injected antibiotics to fight disease. We designed and developed seeds that respond to synthetic fertilizers to increase yields. We bred and introduced animals that produced more pounds of meat or milk per day. It is a methodology that Joe Lewis, pest management specialist with the USDA's Agricultural Research Service, calls "therapeutic intervention."[13]

This approach uses technology to intervene in a system—almost always to eradicate a problem or introduce a desired trait—rather than to understand a system and ascertain how to access its inherent strengths. It almost never uses technology to understand *why* a problem emerged, or what unintended impacts a particular trait may have on a species or its environment, or how the inherent strengths within ecosystems might be harnessed to address the *cause* of a problem or deficiency, and increase the optimal productivity of a system. Based on field experience, Lewis argues that we must now conclude that the therapeutic intervention approach has failed.

This is not to deny some short-term successes using single-tactic technologies. We dramatically reduced the labor required to produce essential crops. We increased the yields of those crops beyond anyone's expectations. And we made it possible for citizens of the United States to spend less of their disposable income on food than any other nation in the world—only 10 percent in 2001 according to USDA/ERS estimates. Spending less of our earned income on food does not, however, translate into cheap food as is often implied. Americans spend more per calorie of food than 95 percent of the rest of humanity.[14]

Unfortunately, these short-term successes achieved at the expense of depleted resources and degraded environments have not prepared us well to meet the complex set of challenges we now face.

The Need for Ecological Sensibility

Our one-dimensional approach to agriculture, which includes the development of seeds and breeds that are responsive to exogenous inputs, was an essential component of the green revolution. And while the green revolution has been properly praised for its success in increasing the yield of a few species of plants and animals, it has, nevertheless, failed us in a more fundamental way. And it is that more basic failure that has positioned us poorly to meet the challenges of the future.

Developing the green revolution seeds and breeds that were responsive to exogenous inputs allowed us, for example, to largely ignore the formative issues associated with deteriorating soil quality and soil erosion. And, as the National Academy of Sciences reminded us ten years ago, we are not likely to see many *additional* yield gains from future technology development without addressing the complex problem of improving soil quality.

Poor quality soils, in turn, deprive us of a series of other benefits that accrue to healthy soils, including the significant contributions that good quality soils make to water quality.[15] Coupled with the excess nutrient application that poor soils require, soil erosion also fosters nutrient pollution in rivers and streams. That pollution eventually contributes to the hypoxic zones in major bodies of water.

Poor quality soils also require increased irrigation, which further depletes aquifers and increases soil salinity. As a result, land degradation has now reached epic proportions. By some estimates, 36 percent of the world's cropland is "losing topsoil at a rate that is undermining its productivity."[16] This does not bode well for meeting the twin challenges of feeding a growing population while reversing environmental degradation—especially in the developing world.

The one-dimensional approach also forced us onto a pesticide treadmill. Our single tactic approach, using pesticides to control target pests, has failed to acknowledge the ecological connections within the system in which the pesticide is applied. As we now well know, pesticides not only kill the target pest, they also harm many beneficial organisms that previously kept other pests in check, creating new pest problems. Since a pesticide never kills all the target pests, those that survive become resistant to the pesticide and produce a new population of hardier pests. In the process, the *source* of the pest problem often is ignored, leaving the system ripe for pest resurgence. Meanwhile, the correlations among soil quality, nutrition, and plant protection remain largely unexplored. And too often the potential human and wildlife health effects of the pesticide are ignored.

The one-dimensional approach of the green revolution also led to greater specialization and intensification that had deleterious effects on local nutrient recycling. Farmers now often specialize in the production of a single crop or animal species. Integrated crop/livestock systems have almost disappeared. Intensified mono-cropping requires the importation of large quantities of synthetic fertilizers which invariably add to nutrient pollution. Meanwhile, intensified animal production units lead to concentrations of manure with no way to economically transport the manure to fields that could use the nutrients. So manure gets applied in higher concentrations than can be utilized by growing crops. And often the manure is applied at inappropriate times because farmers are under immense time pressure owing to the large acreages they must now cultivate to survive economically.

The abnormal concentration of a single species of crop or livestock in fact introduces a familiar ecology/density principle well known in nature. Aldo Leopold observed that principle in action over 50 years ago. No species, he wrote, is "devoid of density controls" and if "one means of reduction fails, another takes over."[17] Nature, in other words, introduces pests and diseases as the means of reducing the grotesque density of a single species. Such density is endemic to industrial crop and livestock systems. As David Tilman reminds us, we should not be surprised that "Hong Kong chicken operations, housing up to a million genetically similar chickens, were susceptible to a rapid and devastating outbreak of disease . . ."[18] Again, this does not bode well for a future plagued by dramatic increases of infectious disease outbreaks.

Economic Consequences for Farmers

That these one-dimensional technologies also have failed to provide *economic* sustainability for farmers is now dreadfully evident. Richard Levins, Department of Applied Economics at the University of Minnesota, and Michael Duffy, Extension Economist at Iowa State University, each have demonstrated this with unusual clarity. Levins points out that "the one consistent part" of the farm economy story of the past 40 years is that "farmers, as a group, have been left out of the enormous growth in the value of what they sell."[19] Levins' work indicates that while *gross* farm income grew dramatically since 1960, *net* farm income remained essentially flat. (See Figure 1)

Duffy demonstrated similar findings regarding Iowa farmers. His research shows that while Iowa farmers succeeded in dramatically increasing their gross income (albeit with the help of government subsidies) between 1950 and 2001, their net income remained essentially flat through most of that period. His study revealed that nearly all of the farmers' yearly gross income was used to pay the expenses required to produce the income! (See Figure 2)

The reason for this continuing dysfunction in the farm economy is not hard to pinpoint. Purchasing single tactic solutions that fail to address the source of production problems and simultaneously fail to take advantage of the inherent strengths in a system places farmers on an input purchasing treadmill that requires them to buy more and more of the solution. That treadmill, furthermore, puts farmers under constant pressure to add more units (animals and/or acres) to their farms each year to generate more gross income just to pay the previous year's bills. It is the only way they can stay in business.

As a consequence, of course, farmers are increasingly forced into predatory behavior, using any competitive advantage to acquire their neighbor's land, to borrow ecological or social capital from their communities, or to collect public subsidies. Farmers are no doubt aware that this increases their density/ecology problem, but it is the only survival strategy available to them.

Seeds and Breeds for the Future

So we are now reduced to using a few varieties of high-yielding crops and animals (albeit at the expense of enormous input cost to farmers and ecological cost to the environment), but we also are left with compromised production systems that are incapable of meeting the challenges we will be facing in a decade or two. "Indeed," as David Tilman suggests, "the green revolution and the large-scale livestock operations that have come with it are reminiscent of the early stages of the industrial revolution, when inefficient factories polluted without restriction . . . a greener revolution is needed—a revolution that incorporates accumulated knowledge of ecological processes and feedbacks, disease dynamics, soil processes and microbial ecology."[20]

So what kind of seeds and breeds do we need for our new century? How do we develop them? How *do* we "green" the green revolution?

Perhaps the greatest drawbacks of the seeds and breeds we developed for the last half of the 20th century are the simplification and specialization that they fostered. Simplifying production systems to achieve high yields led to a dramatic drop in both landscape and genetic diversity. The most important task facing us as we struggle to meet the challenges facing agriculture in the decades ahead is to redesign the system—to restore agriculture's diversity, to reincorporate part of its wildness, to reintroduce tight, local nutrient recycling, and to tap into the strengths and productive capacities inherent in every ecological neighborhood. Most of those untapped, inherent forces likely lie in the synergies of multi-species systems.

Altered seeds and breeds shaped the first green revolution. Seeds and breeds well suited to specialized, simplified production systems that required large infusions of fertilizer, irrigation and pesticides, perpetuated those systems. The next "greener" revolution will need to produce seeds and breeds that perform well in diversified landscapes, that optimize the productivity inherent in multi-species synergies, and that perform well in localized eco-systems. The new seeds and breeds must be bred to respond to their local surroundings and be suited to their ecological neighborhoods—to their particular soil type, climate, crop and livestock mixture, and landscape design. Instead of breeding seeds to perform well in uniform, global landscapes that *we* manufacture, they will have to be bred to mesh with the ecology of the local biotic community and local culture of which they are a part. Plants and animals, in other words, may need to tell *us* what *they* need to succeed instead of us telling *them* what *we* need to succeed.

Of course, if we follow this principle we may eventually gravitate to some form of perennialism. In fact, given the challenges that will likely face us as a result of climate change, putting more perennials on many parts of our agricultural landscapes will become mandatory if we are going to hold soils and nutrients in place. Besides, annual plants are the opportunists on nature's evolutionary journey. They take advantage of disturbances, and through the process of succession are eventually replaced by perennials. If agriculture is to meet the challenges ahead, we may need to find ways to adapt to perennialization's evolutionary advantage—and in the process we may solve a host of production and ecological problems currently associated with agriculture.

How will we produce these seeds and breeds? It appears likely they will come only from the efforts of the public sector. The private sector will not be interested in producing seeds meant for local ecologies since they will not generate a sufficiently lucrative return. Most will probably be produced through traditional breeding methods. Seeds and breeds developed to perform optimally in local biotic communities can perhaps be developed most effectively by accessing the inherent strengths embedded in the ecological communities into which they will be introduced.

This does not mean that sophisticated genetic research will not be a part of such future breeding programs. But it likely will be the *kind* of genetic research that helps us better understand the microbial ecology of local systems—not intrusive transgenic technologies that design brand new organisms that will more often than not be alien to their local biotic communities. Besides, as Lewis suggests, the current application of transgenic technologies actually *hampers* our progress toward the development of more ecologically sound strategies. He spells it out for us:

> As spectacular and exciting as biotechnology is, its breakthroughs have tended to delay our shift to long-term, ecologically based pest management because the rapid array of new products provide a sense of security just as did synthetic pesticides at the time of their discovery in the 1940s . . . the crops engineered to express toxins of pathogens are simply targeted as replacements for synthetic pesticides and will become ineffective in the same way that pesticides have.[21]

Recent reports confirming the appearance of Roundup ™ resistant marestail in Arkansas provide early evidence that Lewis' assessment is correct. And farmers, once again, will end up paying the bill---according to some estimates an additional $15 to $18 per acre--- for the intensified pest control technologies they will now be forced to purchase to control this "new" weed.

Again it is not the *type* of technology but *how we use it* that is crucial. There is a critical need to incorporate sound ecological thinking and to include appropriate ecological screens in all of our technological innovations. The development of new seeds and breeds is no exception.

And this is not a new insight. In 1946 Aldo Leopold wrote, "there is an urgent need of predictable ecology at this moment. The reason is that our new physical and chemical tools are so powerful and so widely used that they threaten to disrupt the capacity of self-renewal in the biota." This capacity for self-renewal is what he called "land-health."[22] And as he recognized, it was the biotic community's capacity for self-renewal, *not preservation*, which was critical to *both*, a productive agriculture and a healthy environment, *and* that, in turn, both were ultimately intrinsic to *human* health.

Making a similar case as early as 1939, ecologist Herbert Hanson was optimistic. "I have faith that man is inherently ecological, that he has enough in common with the rest of nature, in spite of his superior mind, so that he, too, cannot do otherwise but to take part in adjustment processes when stabilization has been disturbed."[23] Hanson's optimism was apparently misplaced. But we can't afford to continue to ignore his solicitation.

None of this means that we should summarily abandon mainstream agriculture and suddenly adopt ecologically-based practices. As Carl Jordon has advised, we should begin "a gradual replacement of energy-intensive resource management with management based on an understanding of nature.[24] But it does mean that we should begin now to prepare for that transition by developing the public breeding programs that will provide the kind of seeds and breeds which will perform optimally in ecologically-based production systems. The transition should be gradual, but the preparation for the transition, especially with respect to seed and breed development, is over due.

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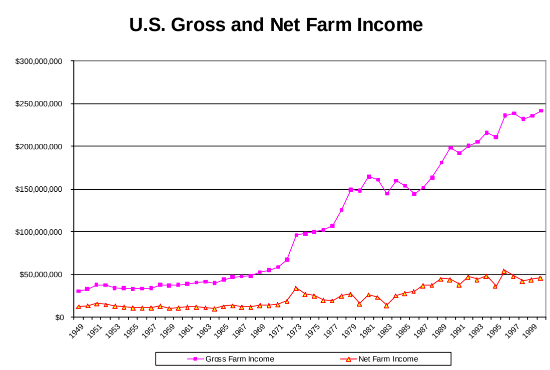

Figure 1

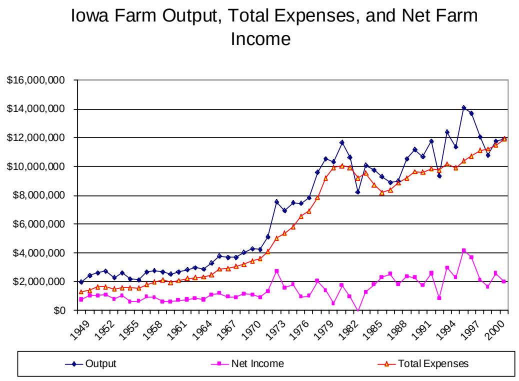
Iowa Farm Output, Total Expenses, and Net Farm Income
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
Output
Net Income
Total Expenses

Figure 2

Twenty First Century Breeding

A Farmers' Perspective

Response to Keynote 1: What would 21st Century Plant Breeding Programs Look Like if They Were Geared Toward a More Sustainable Agriculture-Objectives, Goals. By Fred Kirschenmann

Mary-Howell Martens

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This summer, each time I have driven into town, I have had the opportunity to ponder what I have called "The Tale of Two Soybeans". Ron, a very good conventional farmer, prepared his soil carefully, planted his Roundup Ready soybeans with plentiful chemical fertilizer, sprayed at the right time, and consequently, his field is dark green and vigorous, a wide spread of almost unnaturally uniform soybean-ality without a weed in sight. Guy, on the other hand, is a very good organic farmer. He too prepared his soil carefully, the field coming out of a diverse rotation that provided ample organic matter and microbial activity to sustain a good crop of soybeans. However, it has been very very wet in the Northeast this summer, making it difficult, if not impossible, to cultivate when intended. Guy cultivated whenever the soil was dry enough, but the weeds still grew and now, pigweed and velvetleaf are poking up all over the field.

Ron's field will yield well, enough to cover the substantial cost of his inputs with a little left over, an excellent example of the chart that Fred just used to show the escalating cost of farm inputs relative to farm income. Despite all the weeds, Guy will actually make a better income off his field, the yield will be decent, and there will be enough income to cover the cost of his inputs with some profit. But neither will get rich off their soybeans this year.

As I've been listening to Fred's talk, I've been thinking about the two fields of soybeans and how little we Americans really understand about the rest of the world.
In a post-petrochemical world, Ron would never be able to grow his uniform field of Roundup Ready soybeans. No-till conventional agriculture, pretending that no energy is expended in manufacturing synthetic fertilizers and pesticides and that soil microbes are either not necessary or can thrive without air, will not be the answer. But in a post-petrochemical world, Guy would not grow his field of organic soybeans as he has either. Numerous trips across the field, usually with big John Deere tractors, would not be possible without a plentiful supply of relatively cheap fuel, generous credit, and sophisticated technology. Organic farming, as it is practiced in the Western developed countries, is certainly more ecologically friendly and sustainable than conventional farming, but in some very critical ways, it is not the solution to the coming world agricultural crisis either.

It is difficult for those of us involved in Western agriculture to understand the limitations of agriculture in most of the world. It is tempting to use the same kind of analogies that 'outsiders' use to try to define organic "the same as conventional but without chemicals", defining organic by what it isn't, rather than what it is. But, as organic farmers, we know how dangerously inaccurate that is because we know that organic farming is a totally different thought and decision-making process. We know that, because we have experienced both.

Farming in most of the world is a very different system than what Western farmers are familiar with, with a technology level, decision-making processes, and challenges that are pretty incomprehensible to us. When discussing policy priorities, we must not be so arrogant as to assume that the agronomic, nutritional, and sociological context in other regions is the same as ours, nor that our system is inherently superior.

Indigenous agriculture, as it has been practiced for generations is not stupid, there is a lot of wisdom and well-grounded practices that should be respected and preserved. If we are to ever be successful addressing the agricultural problems in the 21st century throughout the world, breeding must not be done “for” farmers, it must be done collaboratively “with” the recipient farmers, respecting their experiences, needs, and regional knowledge base, blending it with our knowledge, skills and resources, melding the best of all systems to solve the sticky problems.

That said, there are some pivotal factors that transcend regional differences. Perhaps the most critical factor, as Fred so aptly mentioned, is learning how to better maintain soil health and quality, appropriate to the soil type and available technology, with minimal use of petro-chemical inputs. It is indeed alarming that the world population is increasing so fast, just as our current agricultural system seems to be faltering on its chemical foundations. Genetics will certainly play a role in the changing agricultural system, but genetics MUST be grounded in good old-fashioned agronomy. There is simply no substitute for that.

A healthy microbially active soil rich in organic matter will allow precious water to percolate more efficiently and will hold it in the root system which itself will be more extensive and efficient. Even a small reduction of soil organic matter will cut water holding capacity greatly. A healthy soil will also resist erosion and will support crop growth without many outside inputs, especially without the need of synthetic fertilizers. Sir Albert Howard, in ‘Soil and Health’, points out that throughout history, whenever societies removed from the soil than they put back, they rather quickly predisposed themselves to reduced yields, famine and disease. Soil quality management with reduced or no petrochemical-derived fertilizers and pesticides must be the focus of the next Green Revolution.

Biotechnology should certainly be part of this focus. Dr. Janet Thies is doing some exciting work at Cornell characterizing different soil microbial communities and the effect of different inputs using biochemical and molecular markers. This is really valuable information for defining what soil health is and how to evaluate and change it. But biotech crops should not be used as a substitute for changing detrimental agronomic management practices. Fred is right in saying that the current application of transgenic technologies seems to be hampering our progress toward more ecologically sound strategies - that is just what we are seeing too. Far too few young plant breeders appear to have an interest or experience in agronomy or the practice of farming. But biotech can and should certainly be part of the overall solution, when it is applied in a more appropriate manner.

Breeding and soil quality are integrally linked. Over the past 50 years, plants have been selected to respond to high levels of soluble synthetic fertilizer and pesticides, while animals have been selected for rapid gain or milk production on a grain-rich, antibiotic-laced diet with minimal grazing. Even if these were not the actual conscious selection criteria, they became powerful unconscious criteria when these were the conditions that breeding lines were grown under. Our Western agricultural system has created a huge fertility demand in one location, and a huge fertility waste problem in another, with massive amounts of energy needed to haul it in (the fertilizer) and haul it out (the manure). It has also resulted in crops and animals that need substantial chemical intervention just to stay alive. In a post-petrochemical world, initial breeding and selection must be done under reduced input conditions, and there should be more effort placed on balancing the input needs of plants with the output of animals.

Western-style row crop continual monoculture that relies heavily on synthetic fertilizer and pesticides generally does not heal a fragile soil or develop long-term sustainable soil quality. As plant breeders look toward the future, especially in developing countries struggling to feed their growing population, it is critical to look at the system through the lens that assumes that adequate crop rotation is absolutely essential. Continual production of the same high yielding crops on a field will not sustain and enhance the soil. The repertoire of nutritious and productive crops must be large and complementary enough so each year, adequate food production is insured with adequate crop rotation on the available land.

As wheat breeders develop new varieties, they must ask themselves, “What will farmers rotate this wheat with and how long must be the rotation?” and make sure that there are other regionally adapted crops that are economically, agronomically and nutritionally worthwhile that complement the new wheat variety and will prepare the soil well for another crop of wheat in a few years.

As plant breeders select varieties for current and coming agricultural conditions, it is essential to consider long term productivity, not just short-term gain. Roundup resistance for weed control is such a good example of this, with a very predictable precipitous drop in effectiveness once weed resistance increases. But so also are crops that are genetically modified to grow under low fertility conditions. They may appear to work for a few years, but unless the fundamental fertility problems are addressed, such crops will simply further mine the fragile soil of its already limited nutrients, leaving it more depleted and unable to grow nutritious plants. Its really not much different from our farm checkbook - you can’t keep taking more out without putting back, at least not for very long! It is really not a worthy use of genetics to further impoverish an already depleted soil.

Any new variety that is more efficient in extracting nutrients from the soil must be paired to an effective program to bring nutrients back. Plant breeders must consider what other crops can be profitably and sustainably rotated with new variety that will also replenish the soil.

From my perspective, some of the goals of twenty first century breeding must be:

1. Twenty-first century breeding must move beyond its often current role of developing short-term “Genetic Band-Aid” solutions to agronomic management problems. Soil health must be a major focus of 21st century worldwide agricultural development, as should the long-term agronomic sustainability of the entire system.

2. Twenty-first century breeding must attempt to predict what agriculture will be like in a post-petrochemical world and then prepare for those conditions, developing a diversity of different crops that yield well with reduced outside inputs.

3. Twenty-first century breeding must take adequate crop rotation into account, developing a repertoire of crops for different regions that are complementary nutritionally and that work well together in a healthy crop rotation to build soil quality and soil nutrient status.

4. Twenty-first century breeding must address the complete balanced nutritional needs of the burgeoning world population and then assemble improved regionally adapted crops and animals that can promote regional self-sufficiency.

5. Twenty-first century breeding must actively include the recipients in the planning, selection and development process, so the breeding is done with the recipients, not simply for the recipients.

Plant Breeding Unbound: Opportunities Created by Breeding for Sustainable Systems

Response to Keynote 1: What would 21st Century Plant Breeding Look Like if They Were Geared Toward a More Sustainable Agriculture-Objective, Goals by Fred Kirshenmann

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Introduction

Vast opportunities will be available to a plant breeding profession that works in the manner that Bill Tracy has described, and which has as its goal the kind of agriculture Fred Kirschenmann described. I will discuss some of the new genetic territory that will be opened up and the straightjackets that can be removed from plant breeding in this new century.

Local Adaptation

One of Fred's points bears repeating:

> Instead of breeding seeds to perform well in uniform, global landscapes that we manufacture, they will have to be bred to mesh with the ecology of the local biotic community and local culture of which they are a part.

Corporate plant breeding is ill suited to meeting that goal. Corporations have certain built-in functions: to maximize profit, increase market share, and expand geographically. For seed firms and their parent conglomerates, those goals are best met by developing a few standardized big-sellers – the crop variety equivalents of Celebrex or Viagra. State experiment station breeding programs that support themselves by marketing varieties are under similar pressures.

The structure of most public breeding programs, with testing locations scattered across a state, *is* compatible with breeding for adaptation to local ecosystems - provided that local adaptation is an the explicit goal, and the outlying locations are used for selection in early generation, not just advanced yield testing. This, of course, would require significant increases in funding of public breeding programs.

Local, privately owned seed companies are also in a good position to breed for local adaptation, provided they have the resources and can survive in the market.

Breeding freed from its straightjackets

Imagine that the target for the crop varieties we're breeding is an agriculture that is free of, as Fred said (quoting Aldo Leopold), the "grotesque density of a single species" that invites pests and pathogens. Then we will be able to shake off, to some extent, the heavy burden of resistance breeding that takes up 40 or 50 or 90 percent of the time and effort expended by today's breeders and biotechnologists.

During 13 years in USDA-ARS, I spent most of every day battling wheat leaf rust – a fight that the breeders will never win as long as there is a solid carpet of uniform wheat varieties through the center of the continent from Mexico to Canada. Today, most public wheat breeders I know receive funding to work on scab resistance, with scab epidemics occurring only because of unsustainable cultural practices like wheat-corn rotation. And that funding claims a huge share of their daily breeding efforts. Wheat varieties for south-central Kansas and north-central Oklahoma now are required to have acid-soil tolerance, a consequence of long-term use of acid-forming N fertilizers. Industrial agriculture may have made the Green Revolution possible, but it has also saddled breeders with a lot of extra traits to breed for.

Plant breeding could be freed in another direction as well by its re-invigoration as a public service - freed from the many practical straightjackets in which it has become bound as a result of intellectual property rights.

There is a perennial debate about whether the resources put into hybrid corn breeding since the 1930s could have been put into open-pollinated variety breeding with similar improvement. That's a hypothetical argument in which I won't take sides.

Nevertheless, if there is a question with regard to corn, there seems to me little doubt that grain sorghum - a largely self-pollinated species – need never have been grown as an F_1 hybrid crop. But since the 1950s, the U.S. private sector has made it one, out of "corn envy" and to ensure yearly seed sales. Vast amounts of time and energy are sacrificed, and potentially useful germplasm passed over, for the sake of maintaining the cumbersome cytoplasmic male-sterility and restorer system. Public sorghum breeders, who feed germplasm to the private sector, have had to go along.

The same strategy – substituting hybrids for varieties - was tried for many years by wheat breeders and geneticists but without success, because hybrid breeders were having to compete with non-straightjacketed variety breeders. That hybrid effort has been all but abandoned in favor of patenting individual genes, a simpler tactic for cultivating intellectual property rights. The two most serious ways in which genetic engineering and patenting hamper plant breeding are restrictions on the movement of germplasm, as Cary Fowler describes in his paper, and the sapping of funds that could otherwise be used more effectively to support the kind of plant breeding that produces truly new cultivars. Major Goodman at NC State has calculated that for the cost of developing, testing and releasing a single genetically engineered corn inbred, a program could produce 28 genetically diverse inbreds from temperate x tropical crosses, and on the same time scale (Cox, 2002).

The Importance of Selection in the Field

Bill emphasized the importance of phenotypic selection. Despite the molecular scale at which it works, genetic engineering is a blunt instrument. Genetic engineers have a problem: They can dramatically manipulate traits that are genetically simple and mostly irrelevant to the type of agriculture that Fred has described, but they are incapable of steering an entire genome, highly integrated and buffered as it is, toward better functioning as part of an ecosystem. Only by evaluating the total plant phenotype can we do that.

We can learn much from analyzing the genomes of breeding populations, and even make marginal improvements in efficiency. Leaving aside crude transgenic technology, there are many analytical technologies that will improve our understanding of what we are doing as breeders. But unless genotypic data are associated with phenotypes over a sufficient number of seasons and locales, under careful observation, they are perhaps worse than meaningless. If breeders in the 21st century spend much more time looking at computer monitors or printouts than they do looking at the plants themselves, in their ecological context, we should not expect useful results.

But let me emphasize that there are dangers in being reflexively anti-technology. In fact, under rules under discussion in Europe for plant varieties to be used in organic agriculture, most of the germplasm being developed at The Land Institute, where I work, might be banned (Lammerts et al., 2002). We use old-fashioned but essential techniques such as embryo rescue and chromosome doubling with colchicine that may turn out to be unacceptable to some of our more fastidious friends across the Atlantic.

To the extent technology enhances our ability to produce hybrid populations through sexual means, and, as an adjunct to field observation, to select the right plants and families within those populations, it is our friend. To the extent that it is used to bypass the creative forces in breeding – meiosis, fertilization, and phenotypic selection - in search of a shortcut, it is a distraction.

The Need to Breed Perennial Grain Crops

Fred goes on to say that if we follow the principle of integration into local ecosystems, we "may eventually gravitate toward some form of perennialism." I would strengthen that statement. If we leave this critical move up to gravitation, it won't happen; where the big decisions are made in agricultural research, it is not gravity but inertia that rules. We must move as quickly as possible toward perennial cover on most of the landscape.

Fred mentioned some frightening soil-erosion data. And soil is a nonrenewable resource, since we aren't able to practice crop rotation over a geologic timescale. Perennial vegetation covered most of the earth before agriculture. For millennia, it held onto soil that is currently being lost in a relative blink of an eye. In the past century, we have compensated for some the effects of erosion by substituting oil for soil, but that won't be feasible in the long term. No-till agriculture is too chemical-intensive, it has no deep roots during the rainiest parts of the year, and it improves the infiltration properties of soils. Therefore, the leakage of water, nutrients, and chemicals can be worse under no-till than with conventional tillage (Dinnes et al., 2002).

Of course, we have a problem: Our human population can't exist on fruits, nuts, and grass-fed meat – the kinds of foods which, although supported by existing perennial species, do not supply a large fraction of human caloric intake. We get the bulk of our calories from grains, and there are no perennial grain crops. That is where we as plant breeders have an unprecedented opportunity. As my colleague Lee DeHaan has put it, sustainable agriculture research has necessarily attempted to mitigate the effects of agriculture by concentrating on the "software" – that is, putting our research, experience and knowledge into practice using our existing crop and forage species – because we are stuck with "hardware" – that is, crop species – that are not radically different from those that led us into industrial agriculture. To open up possibilities for truly new agriculture that is sustainable in the long term, new hardware – a range of perennial grain crops - is needed.

Many plant breeders have long had difficulty finding their place in sustainable agriculture. Now we have a clear-cut, difficult, but achievable mission laid out for us: to develop new hardware - i.e., perennial grain crops - that will make agriculture sustainable for the first time ever. This will be a huge effort that must extend far beyond The Land Institute (Cox et al., 2002) and Washington State University (Scheinost et al., 2001), with at least some effort in every agronomy and plant breeding department. While aimed at a practical problem – *the* problem of agriculture – this new breeding effort will open up whole new territories for basic research in genetics and plant science.

Breeders live in the future. Even in well-established crops, the pollinations we made this spring or summer won't lead to cultivars until we're well into the next decade. Breeding cultivars only for currently available farming systems will become a self-fulfilling prophecy. If we as a group are to continue addressing the role of public and nonprofit plant breeders in sustainable agriculture, we have to think in the long term. And "long term" implies breeding perennial crops, including grains.

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Breeding for Sustainable Cropping Systems

Response to Keynote 1: What would 21st Century Plant Breeding Look Like if They Were Geared Toward a More Sustainable Agriculture-Objective, Goals by Fred Kirshenmann

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As we think about directing plant and animal breeding efforts toward the development of sustainable cropping systems, we face four major challenges. (1) Sustainable cropping systems will require the cultivation of a more complex mixture of crops than those present in current systems in order to develop a multifunctional agriculture, designed to provide economic, environmental, and cultural benefits to society (Brummer, 1998; Kirchmann and Thorvaldsson, 2000; Vereijken, 2002). (2) These new systems will have properties different from current systems and these properties will affect the goals and possibly the methods used by plant and animal breeders. (3) Public breeders require support scientists in allied disciplines to produce viable new cultivars and breeds. (4) Mechanisms for the production, distribution, and marketing of seed and breeds of alternative species need to be identified and/or developed to ensure their integration into farming systems.

Current government agricultural subsidies must be restructured

As Fred Kirschenmann's paper (this conference) made abundantly clear, sustainable cropping systems will almost certainly require increased crop diversity. Given that the current crop diversification in many parts of the Midwestern U.S. ends with maize and soybean, this will require radical change. A hallmark of modern cropping systems in the United States is their lack of crop diversity. A visual representation of the loss of diversity in Iowa over the past 50 years is shown in Figure 2 of Keller and Brummer (2002): a plethora of crops, grown on many small farms after World War II, has given way to large farms growing only two crops.

For more than forty years, the yield of maize, rice, wheat, and soybean has increased substantially in the United States and much of the world (Hafner, 2003; Specht et al., 1999). Plant breeders typically take credit for at least half of the yield improvement (Duvick, 1992). However, while production was soaring, the value of maize per acre, in inflation adjusted dollars, was souring (Fig. 1). Most plant breeders do not take responsibility for the decline in value that accompanied their breeding success.

We might reasonably question why this reduction of crop diversity has taken place. One place to look is at the net returns for various crops. The conventional wisdom holds that the ascendancy of maize and soybean derives from the fact that they are more profitable to produce than alternative crops. However, the data in Table 1 show that in the absence of government payments, production of both maize and soybean bleeds red ink, but in contrast, alfalfa raises significant capital for the wise farmer without the need of the government largesse lavished on row crop producers. I do not mean to imply by these data that the solution to our current agricultural problems is only the cultivation of alfalfa, but that alfalfa and other crops have an important role to play in that solution.

Thus, corn and soybean are widely grown in large part due to government farm programs that guarantee a small profit regardless of production or market price. This small profit necessitates cultivation of ever larger acreages to make farming economically feasible. If not for the government payments, Iowa net farm income would be close to, or in, negative numbers. The importance of these numbers is hard to miss. Alternative crops will not be cultivated to a great extent until this situation changes. In turn, public breeders who would developed improved varieties of crops that are unlikely to be cultivated will not be supported by lawmakers faced with tight budgets.

Alternative systems require changes in breeding strategies

The great Swedish filmmaker, Ingmar Bergman, in describing his method of producing both excellent plays and movies, once said, "I devote myself to a kind of crop rotation. I have a piece of land, and sometimes I cultivate rye and sometimes clover." (Cowie, 1992, p. 106). Not only did he realize the benefits of crop rotation, he also wisely included a perennial crop in his system. Another noted Scandinavian, Søren Kierkegaard, wrote in *Either/Or* (1971, p. 288) about "the rotation method" as a way to alleviate boredom: "My method does not consist in change of field, but resembles the true rotation method in changing the crop and the mode of cultivation. Here we have at once the principle of limitation, the only saving principle in the world. The more you limit yourself, the more fertile you become in imagination."

What Bergman and Kierkegaard both realized, however removed they may have been from actual agricultural practice, is that crop rotation makes intuitive sense and it works. The maize–soybean rotation mentioned previously is hardly worthy of the term, including as it does two annual crops, both with similar developmental trajectories. It is more a continuation of monoculture than a sensible rotation strategy: the soil still erodes, chemical weed and pest control and fertilizer amendments are required, and perhaps worst of all, pest cycles are not easily disrupted. (One insidious pest, the western corn root worm has devised an elusive strategy enabling it to survive the soybean phase of the rotation, ready to attack when the maize returns (O'Neal et al., 2001)).

Well designed and thoughtfully constructed crop rotations do not exhibit the breakdown endemic to modern industrialized systems (Liebman and Dyck, 1993; Peters et al., 2003). Numerous biological and soil chemical and physical properties have been shown to be superior under an organic compared with a conventional management system, even where the same crops and cropping sequences were included in both systems (Mäder et al., 2002).

These alternative systems, which offer a number of environmental and other benefits over conventional systems, will present plant breeders with a substantially different selection environment than that currently being used. In the simplest case, the breeding objectives of our traditional crops will likely change. Different pests may manifest themselves in a different system (Krupinsky et al., 2002). For instance, moving to low- or no-tillage systems has resulted in an increase in grey leaf spot in maize (Ward et al., 1997) and in the disease take-all in wheat (Cook, 2003). Thus, even if the same crops are grown in the same rotations but under different management practices, the selection targets on which breeders are focusing their programs may change.

Further, moving to a more complex rotation means that the traditional crops may need to be modified to fit with other system components. For example, perhaps shorter season maize hybrids should be grown to enable reliable cover crop establishment in autumn. More saliently, a complex agroecosystem means that goals and solutions must involve not only breeders but also agronomists and other professionals who weigh the relative merits of breeding for a specific trait versus growing a different species.

Second, mixtures will likely become more common in the agroecological landscape. Cultivar mixtures of a single species have been tried at various times to reduce disease incidence and to hedge against vagaries of weather (Smithson and Lenné, 1996); a compelling example on a large scale of the value of such mixtures has been recently demonstrated in rice (Zhu et al., 2000). Further, intercropping, such as maize and beans, may become an important component of the cropping mix in sustainable systems. In both cases, plant breeders will need to examine selection methods used for mixtures, and determine if selection of each species independently is acceptable.

Third, radically different views on how agricultural systems should be constructed are being voiced, such as Wes Jackson's *New Roots for Agriculture* (Jackson, 1980). Among the possibilities are perennial grain crops, which will entail a long term endeavor representing an ideal mission for public plant breeding (Cox et al., 2002; Scheinost et al., 2001). Stan Cox presented a brief summary of this work in this conference.

Fourth, and perhaps most importantly, other crop species will need to be developed as we move toward a truly sustainable cropping systems. If all research effort is devoted to only a few major crops, then *of course* no other crop will have its performance enhanced to a level that makes its inclusion in the system viable.

Although many lists of the actual qualities a sustainable cropping system needs to possess can be compiled, one aspect that uniformly occurs in them all is the conservation of soil. In order to effect this goal, continual cover on the soil will be necessary to minimize wind and water erosion. Crop residues may aid this effort in some cases, but a more encompassing approach is that of perennialized landscapes, in which perennial grain and forage crops, cover crops, living mulches, and annual crops are organized into a complex system whose emergent properties include soil retention, water infiltration and purification, nutrient recycling, and, of course, adequate production of food, feed, fiber, and fuel.

Many crops that could fit one or more of these niches are not being bred, or even evaluated, widely. However, in order to argue that these crops should be the focus of publicly supported breeding, the value that these crops bring to the cropping system needs to be addressed. Our current production systems place value on individual commodities, yet a cover crop has no commodity value. If we move to a mindset that places value on entire system performance, then the value of these crops becomes evident, particularly if all externalities are included in our accounting.

How is breeding impacted by the move toward alternative sustainable cropping systems? First, different systems have different biological properties. Cultivars selected in one system may not be optimum for another, and therefore, breeding under the alternative system should be considered. Simmonds (1991) made the following statement regarding selection in low yield versus high yield environments, but it may be generalized to any contrasting systems: "The sensible response by plant breeders seeking to breed for [a particular environment] would be to select in [that environment]; to *select*, be it noted, not merely do trials after selecting in [another environment]." Nevertheless, the need to breed *within* alternative cropping systems will almost certainly be dependent on context: on the crop being bred, the system in which the crop will be grown, the knowledge of the farmer, and the location of the field. In some instances, selection in one system will be perfectly fine for production in the other.

Second, the breeding methods will remain the same regardless of the selection environment. Sound genetics and breeding theory must remain at the forefront of public plant breeding, whether university based or participatory. Wishful thinking, a desire to conserve heirloom plants and animals, and an interest in historical farming methods are all fine, but they should not be conflated with plant breeding. The only case in which different breeding methods may need to be considered is in the case of intercropping, where several crops may need to be selected concurrently. Several schemes have been designed for this situation (Hamblin et al., 1976; Hill, 1996), although further work in this area is probably warranted.

Third, different cropping systems will have different target environments, which almost certainly means that different traits will be the targets of selection. It is important to realize, however, that breeding is a long term endeavor. Continual switching of cropping systems, of targeted traits, and of the crops included in the mix may be necessary from an agronomic or economic perspective, but for a breeding program, such changes are devastating. Clear formulation of breeding goals, therefore, needs to be undertaken by the breeder in close consultation with the farmer, the consumer, and the environmentalist to ensure that the result of a long term project–ten years at a minimum–will not be wasted.

Viable public breeding needs support scientists

Most of the focus on public plant and animal breeding has been on the breeders themselves. However, breeders do not operate in a vacuum. Plant breeders rely on strong support from allied sciences, such as entomology, plant pathology, plant physiology, animal science, food science, and others to help develop the plant most useful to the intended users and consumers; likewise for animal breeders. In many areas of science, though, such *applied* scientists are no longer being recruited by universities. Thus, a breeding program that needs to select for resistance to a new disease but does not have pathology support may have a difficult time doing so. The importance of supporting sciences to a viable public plant breeding program is not widely appreciated, but it is crucial to the maintenance of public programs.

Seed production and release strategies must be developed

Finally, public breeders may do a good job producing improved germplasm and cultivars, but their ability to produce, distribute, and market the seed is limited. For some crops, such as wheat, clear mechanisms are in place to get seed from the breeding program to the farmer. But for other crops, difficulties remain. The seed production areas for some crops lie outside the primary area of cultivation, so breeding needs to occur in both environments to ensure adequate production of both the useful product and of seed. Long distance coordination is difficult, particularly when decisions on hiring are not made in consultation across state lines. Further, when seed production is outside the state in which a breeder is located, the role of the university in producing seed is diminished, and other arrangements are needed.

A final issue that needs to be considered, but is beyond the scope of this paper, is the use of exclusive versus open releases of cultivars. Publicly developed cultivars of some minor crops, including many forage crops, have languished on the shelf when given an open release because no company was willing to produce seed, yet when released exclusively to one company, publicly developed cultivars have done well. For those crops in which the road from breeding program to field is not well established, mechanisms to ensure the most public good from publicly developed materials need to be developed and applied.

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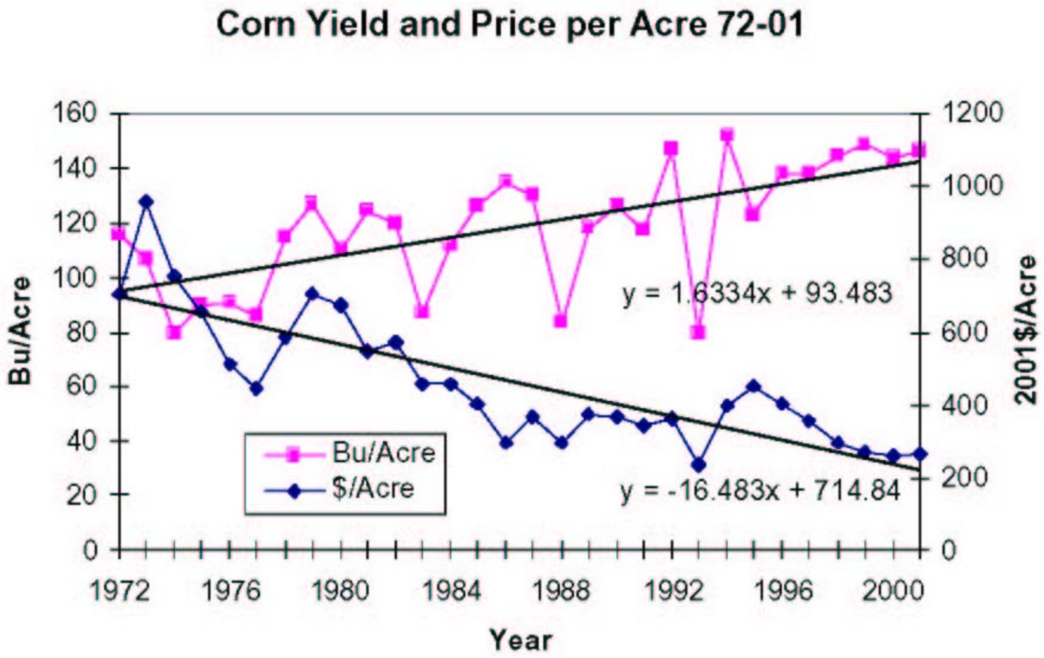

Figure 1. Average maize yields per acre in Iowa and average value of maize per acre adjusted for inflation to 2001 dollars from 1972 to 2001. Acreage, yield, and price values for maize were obtained from the USDA National Agricultural Statistics Service (http://www.nass.usda.gov/ia/) and the costs of production from Dr. Michael Duffy, Iowa State Univ. Ag Economist.

Table 1. In late August 2002, I summarized corn and soybean gleaned from the Chicago Board of Trade and from regional hay markets (http://www.ams.usda.gov/lsg/mncs/ls_hay.htm) and set them beside estimated costs of crop production based on data in the Iowa State University Extension Bulletin "Estimated costs of crop production in Iowa—2003" (http://www.extension.iastate.edu/Publications/FM1712.pdf). I assumed the highest yield listed in the cost of production bulletin for corn and soybean and the lowest for alfalfa hay. I also assumed alfalfa hay quality was 50% excellent and 50% good, and that the costs of production included 1/3 of establishment costs.

Per Acre Basis	**Corn**	**Soybean**	**Alfalfa**
Cost of production	$400.54	$308.18	$293.67
Estimated yield	170 bu	50 bu	4 tons
Price (CBOT, 9/03)	$2.09/bu	$5.19/bu	$87.50/t
Average receipts	$334.40	$271.00	$350.00
Net returns	**-45.24***	**-48.68***	**+56.33**

Keynote 2

Responses

Keynote 2-The Current State of Plant Breeding: How Did We Get Here?

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The First Crop Breeders

Plant breeding began when our hunter-gatherer forebears first domesticated wild plant species that provided their favorite kinds of food. The first breeding took place about 10,000 years ago when wheat (*Triticum* spp. L.) was domesticated in southeastern Asia. Shortly thereafter (in archaeological time) plant breeders created other staple crops such as domesticated rice (*Oryza sativa* L.) in eastern Asia, bananas (*Musa* spp.) in Melanesia, maize (*Zea mays* L.) in Mesoamerica, sorghum (*Sorghum bicolor* L.) in northeastern Africa, and potatoes (*Solanum tuberosum* L.) in the Andean regions of South America (Denham et al., 2003; Harlan, 1992).

How did they do it?

We have no written records to tell us how these pioneers transformed wild species into domesticated cultivars but we can assume that they identified desired plants in genetically diverse populations, saved and then deliberately planted seed of those plants, and gradually, over many years, produced domesticated crops suited to their needs and tastes. The diversity of the progenitor species occasionally would have been increased by natural outcrosses to other species and even other genera, as well as by accumulation of mutations including changes induced by naturally occurring transposons.

Creation of new cultivars

The first domestications were only the beginning. When expanding human populations moved out to new lands, the people carried their cultivars with them. They often would have found that their favorite cultivars were not well adapted to the new growing conditions. But as the farmers saved seed of those plants that survived in the new environments, they gradually changed the genotypes of their cultivars to the point that they were transformed into new and different cultivars with new and different adaptations, genetically and phenotypically divergent from the originals (e.g. Hardon et al., 2000; Ramirez, 2002).

In addition to selection for adaptation to new environments, farmers often selected for new and different kinds of appearance and/or flavors, to suit an increasingly diverse group of consumers who themselves constantly developed new and different preferences for food quality, appearance, nutrition, or taste.

So over the millennia, countless numbers of new cultivars evolved, adapted to all parts of the globe and to a multitude of tastes and nutritional needs. These farmer-bred cultivars are sometimes called “landraces”, to differentiate them from “modern” cultivars developed by professional plant breeders (Zeven, 1998). Germplasm preservation facilities (e.g., those of the U.S. National Plant Germplasm System) house seeds of thousands of landraces (and also of wild relatives) of each of the major crop plants, collected from farmers in all parts of the globe (Board on Agriculture/National Research Council, 1991).

Modern Plant Breeding: “Scientific” and “Professional”

Modern plant breeding got underway in the 19th century as knowledge of the role of male and female flower parts evolved and people learned how to make deliberate crosses between individual plants with intention of developing new breeding populations (although in those early days they did not use that technical term). Modern plant breeding was further inspired by the rediscovery of Mendel’s principles of genetics at the turn of the 20th century (Walker, 1966). Next came the development and use of statistics to analyze and design breeding trials and experiments (e.g. Smith, 1966; Sprague, 1966).

With these new tools of genetics and statistics, modern plant breeding developed rapidly during the first decades of the 20th century, and large numbers of improved cultivars of major field and horticultural crops attested to its success.

But science and technology could not do the whole job. The most productive and skillful of the “modern” professional plant breeders employed (and still do employ) empiricism and intuition, in addition to science, to bring about their desired result: a constant succession of improved cultivars. Thus, today's professional plant breeders continue the tradition of their "unscientific" forebears (Duvick, 2002).

Professional Plant Breeding in the Early Years: 1900-1950

Plant breeding in the first half of the 20th century developed simultaneously in two sectors, public and private.

The goal of public sector breeders was to make public goods to satisfy the public good. In the U.S., the land grant universities and the USDA were empowered (and funded) to do public plant breeding.

The goal of private sector plant breeders was to make private goods to satisfy the public good.

Thus both categories of breeder intended to satisfy the public good — to provide cultivars to benefit the public — but they utilized different ways (and often different products) to do so. Cultivars classified as public goods were available to all without charge. Cultivars classified as private goods were proprietary and could only by obtained with consent of their owners (usually for a price) (see pp. 2-9 in Pray and Naseem, 2003).

In the early years of the 20th century, private sector breeders in the U.S. were small in number and had few products. They chiefly produced horticultural seeds and a few varieties of open pollinated maize. Luther Burbank (Encyclopaedia Britannica, 1983; Toth, 1998) was perhaps the most famous of the early private sector plant breeders in the U.S..

Then, starting in the early 1930s, hybrid seed corn companies arose by the dozens, and their maize hybrids dominated U.S. Corn Belt plantings by 1940, and virtually all U.S. maize acres by the 1960s (Griliches, 1988; USDA, 1944-1962).

In the first half of the 20th century public sector plant breeding in the U.S. was the only actor on stage for all field crops but maize. And the public sector was also active and important in maize breeding. Public sector and private sector maize breeders interacted collaboratively to produce the final product, improved maize hybrids. All concerned acknowledged that the public sector was the senior partner, with the strongest scientific knowledge and best research facilities. Public sector plant breeding also was relatively well funded for breeding of numerous crops in addition to maize, in those early years of the 20th century.

Professional Plant Breeding in Recent Times (1950s to Present)

Public sector plant breeding: Activities

Plant breeding in the public sector continued to build on its successes of the early half of the 20th century but tended to reduce output of finished cultivars for crops (such as maize) where the private sector had increased its output. Public sector research for such crops moved more heavily into basic investigations (Pray, 1991) and building of useful new germplasm pools. But both basic research and applied research (e.g., cultivar development) continued in the public sector for those crops and those regions that were not served or were only lightly served by the private sector. One such example would be hard red winter wheat, for the southern Great Plains of the U.S.

Public sector plant breeding: Funding

Concomitant with increased mechanization, the number of farms and farmers in the U.S. declined steeply in the latter half of the 20th century. The decline was not a new phenomenon; it continued a trend that was underway at the beginning the 20th century (USDA/NASS, 2003). By the end of the 20th century less than two percent of the U.S. population was engaged in farming, yet food was plentiful and low-priced, and staple crops actually were produced in surplus.

Perhaps not by coincidence, interest in and financial support for public sector plant breeding began to wane in the final years of the 20th century and the trend continues in the 21st century as well (Heisey et al., 2001). This contrasts with funding for private sector plant breeding, which has increased constantly during the same period, to the point that total expenditures for private sector plant breeding in the U.S. may equal or exceed those for public sector plant breeding (Frey, 1996).

Plant breeding in the developing countries

Starting in the decade after the end of World War II, and accelerating in the 1960s, nations throughout what is now called the "developing world" established their own national plant breeding programs, modeled after public sector programs in the industrialized nations of Europe and North America. These programs were part of their national agricultural research systems (NARS) (p. 271, Hayami and Ruttan, 1985).

Additionally, several independent non-profit plant breeding centers/institutes were set up in developing countries, with the mission of breeding important staple crops such as wheat, rice and maize for farmers of the developing world (CGIAR, 1996). The first two were the International Center for the Improvement of Maize and Wheat (CIMMYT), and the International Rice Research Institute (IRRI). Eventually these international centers and others with similar mission and funding organized themselves into a collaborative group called the Consultative Group on International Agricultural Research (CGIAR).

The NARS and the CGIAR centers, acting sometimes separately and sometimes cooperatively, aimed to serve farmers of the developing countries, a heterogeneous group of food producers ranging from subsistence farming smallholders and tenants up to larger scale commercial producers.

Plant breeding in the private sector

Private sector plant breeding — breeding by for-profit seed companies — in the industrialized nations expanded rapidly starting in about the 1960s. Private sector maize breeding expanded from its base in the USA and Canada to Europe and South America, and to a lesser degree to other continents, coincident with increased demand for maize as a feed grain in those regions. Private firms also began breeding and sale of seeds of other hybrid crops such as grain sorghum and sunflower (*Helianthus annuus* L.). Passage of plant variety protection legislation in Western Europe and North America in the 1960s and 1970s (ASSINSEL, 1999; Baenziger et al., 1993; Knudson and Pray, 1991) stimulated commercial breeding of self-pollinated crops such as wheat (especially in Europe) and soybeans (*Glycine max* (L.) Merill) (especially in the U.S) .

Private sector breeding generally did not serve farmers in the developing world, with the exception of larger scale commercial producers of such crops as maize, sorghum and soybeans, in (for example) Argentina, Brazil, and South Africa.

In particular, the private sector could not serve the needs of subsistence or semi-subsistence small farmers in the developing countries, especially those in countries with unreliable markets and/or marketing systems. Such farmers had no incentive (or cash) to make annual investments in purchased seed. Prudence dictated that they use their own saved seed, as their forebears had done since domestication began. These farmers were not averse to new germplasm; they welcomed locally adapted improved cultivars when available, and maintained and used them (sometimes for breeding) instead of or in addition to their landraces (Cleveland et al., 1994; López-Pereira and Morris, 1990).

Unfortunately, many of these farmers, often depending on minor crops or in niche (and often unfavorable) environments, also were not well served by either their NARS or the CGIAR centers for a variety of reasons, both organizational and financial (Hardon, 1995). Thus, they had little or no access, from either public or private sources, to improved cultivars suited to their tastes and growing conditions. This category of "left-out" food producers is not small; although formal surveys have not been made, it may include as many as two billion people.

Participatory plant breeding

Responding to this need, a new concept called "participatory plant breeding" (PPB) was developed and implemented in the latter years of the 20th century. PPB is intended to serve those farmers in developing countries that are not served by either public or private sector professional plant breeding.

PPB has several variations but all emphasize decentralization, strong farmer participation, and on-farm testing. Farmer/breeders and professional breeders work together. Professional breeders advise on breeding techniques but do not dictate, and they also provide useful germplasm (at various levels of development) that the farmers would not be able to access on their own. The ultimate goal is to produce cultivars that meet local farmers' needs and that the farmers can reproduce by themselves (Eyzaguirre and Iwanaga, 1995; Hardon, 1995).

Public sector breeders from universities and various non-governmental organizations (NGOs) including some of the CGIAR centers have partnered with farmers to conduct PPB in appropriate crops and locales in the developing world.

Plant Breeding Today

Division of responsibilities

At the present time, public sector and private sector plant breeders in concert provide the basic and applied research and development that is needed for production of cultivars to suit current needs.

In the U.S., land-grant universities and federal agencies such as the USDA employ public sector plant breeders. Similar situations hold in other nations. Public funds (tax dollars) formerly supported all work of the public sector breeders. The public paid the bills. That situation has changed to some extent in recent years; it will be discussed in a later section.

The CGIAR centers also employ public sector breeders, and their work is funded primarily by government agencies worldwide, plus a few private charities. For the most part, tax money supports the work of these public sector breeders. The public pays the bills.

For-profit seed companies (members of the "agribusiness" community) employ private sector breeders. Income from seed sales to farmers supports the work of the private sector breeders. The farmers pay the bills.

Public and private sector breeders work separately but also together; they depend upon each other for germplasm, for technology, and for general advice and counsel about breeding. They all serve the farmer and, indirectly, the consumer.

In regard to field crops, the public sector breeders have the broadest mandate, to produce public goods (public cultivars) wherever needed, and they have the most freedom to decide what to breed, e.g., what qualities or traits the cultivars should have, what adaptations, and what customers should be served. However, political and/or fiscal limitations can restrict the public sector breeders' opportunities for action.

The private sector breeders have a narrower mandate. Because their living depends on successful sales of the cultivars they breed, they are forced to produce only cultivars of the kind, quality, and price that the farmers will buy ("If I don't like it I won't buy it; if I can't afford it, I won't buy it.") Consequently, private sector breeding of the field crops is confined to a relatively small number of major field crops, those with sufficient seed market size and profitability to warrant private investment in plant breeding research and development.

Further division of responsibilities

To some extent private and public sectors do the same things but each sector has its own specialties. Public sector breeders in the universities have the important responsibility of education — of teaching the theory and technology of plant breeding — as well as of conducting basic and applied research in plant breeding. Publication of their research results in peer-reviewed journals is also a major requirement.

Public sector breeders in government agencies conduct and report results of basic and applied research and some are charged with the vital task of germplasm conservation.

Public sector breeders at the CGIAR centers are concerned primarily with product development and delivery to smallholders in developing countries worldwide, but they also have a vital role in germplasm collection and conservation of the crop(s) bred by their center.

Private sector breeders in the seed companies primarily develop improved cultivars for commercial farmers worldwide, although in recent years some of the larger companies have also invested heavily in more basic kinds of research in molecular biology, with intention to apply the results to plant breeding.

Relative amounts of public and private sector plant breeding

Table 1 summarizes one of the few surveys of the relative effort devoted to public vs. private plant breeding in the U.S. It shows that in 1994 private sector breeders outnumbered those in the public sector for maize, soybeans, cotton, and sorghum, but public sector breeders were more numerous than private sector breeders for wheat, forages, and potatoes. For rice breeding, numbers were about equal for both classes.

Table 2 provides a current estimate of the global impact of private sector breeding and seed sales for four of the major field crops. Despite the predominance of private sector cultivars in maize plantings of the industrialized countries, private sector cultivars account for less than a third of the planted area in developing countries, and globally they are planted on less than 50% of the area devoted to this crop. Although estimates for soybeans are less precise, their figures show about the same differentials as those for maize. Private sector impact on wheat and rice plantings is inconsequential globally, although private sector cultivars of these crops do predominate in some regions such as Western Europe (wheat) and California, U.S.A. (rice).

Thus the figures in these tables show that despite the predominance of commercial plant breeding for a few crops in a few regions, the public sector (including farmer-breeders) still dominates globally. It is highly important and often indispensable.

Global Trends

New technologies for plant breeding

During the past half century, plant breeding of field crops, especially in the industrialized countries, has benefited from introduction of technological aids such as mechanization of the planting and harvest of performance trials, and use of computers to record and analyze data. In the past decade, breeders have begun to use the aid given by various techniques of biotechnology such as marker-aided selection, genetic transformation to introduce useful genes from distant species, and genomics analysis to increase understanding of the genetics of key physiological processes such as those that affect grain yield, plant morphology, stress tolerance, and resistance to destructive disease and insect pests (Duvick, 2002).

Increased expense of plant breeding

Although these technological aids increase the precision and speed of cultivar development they also add to the expense of breeding. The expense per unit gain in yield and other performance traits goes up each year, in part because of the added cost of the new technologies but also (and most importantly) because genetic improvement requires increasingly more breeding effort as cultivar performance approaches a maximum achievable level.

Within limits, private sector breeding can accommodate this increased cost of breeding, as long as farmers can afford to pay for increasingly expensive seeds. (Even here there must be some limit at some future time, based on profitability, to the farmer, of the improved cultivar.)

Public sector breeders on the other hand are faced with a double challenge: (1) increased expense per unit of gain and (2) reduced funding of their plant breeding activities. This double-dose problem is especially perturbing because of the essential role public sector breeding plays (as noted above) in breeding of crops that are not dealt with by the private sector. Of special note, the public sector is virtually the only potential provider of breeding for minor crops, non-commercial crops, or crops grown in niche environments (Frey, 1996; Frey, 1997).

Reduced funding for public plant breeding

Reduced funding of plant breeding in the public sector no doubt is the product of many interacting forces in society, some of which were discussed in an earlier section. In the following, I list some other possible reasons for reduced interest in and funding of private sector breeding.

Belief: The private sector "can do the job". A presumed ability of commercial plant breeding to fill all needs in plant breeding has been used as an argument to reduce support for public sector breeding:

> Some question the need for continued public funding [of agricultural research], thinking that … the private sector will do the job (Pardey and Beintema, 2001).

Fact: Economic and social disasters. A very different reason explains low support for public sector breeding in many developing countries. Economic and social hard times (often disastrous) have caused reduction or elimination of public funding for many beneficial public interest programs including plant breeding.

Fact: Economic overabundance. In the industrialized countries it may be that the opposite condition — unprecedented good times — has a negative effect on funding for public sector plant breeding. In the U.S. for example, less than two percent of the population are engaged in agriculture, and most of the well-fed urban dwellers are several generations removed from farming and so have no appreciation of or particular affection for agriculture. Major crops such as wheat, maize and soybeans are produced in worrisome surplus, food costs are low, and a major concern about food in the U.S. is that too many Americans overeat. There would seem to be no need to fund plant breeding, if its chief purpose is to ensure ample food supplies.

Even in regard to food production for the developing world where great numbers of people are chronically malnourished and underfed, claims like the following are made repeatedly:

> The biotechnology industry claims it holds the answer to world hunger: *high technology to increase production*. But according to the United Nations Food and Agriculture Organization (FAO), this badly misstates the problem. There is no shortage of food in the world. Per capita food production has never been higher (Turning Point Project, 1999).

In this statement as in others like it, the “biotechnology industry” is equated with commercial plant breeding, and, therefore, whether intended or not, the forceful statement, “There is no shortage of food in the world,” leaves the impression that plant breeding of any kind, public or private, is unnecessary, at least for increased food production. Public sector breeding is hit (“collateral damage”) in the attack on private sector breeding.

Belief: Plant breeding harms the environment. The chief publicity given to food production activity today is that farming, especially in the industrialized countries, causes environmental problems. Modern crop production more often than not is said to be equivalent to environmental disaster, especially if farmers use synthetic fertilizers, pesticides and herbicides, plus modern “high yield” cultivars which are said to require such supplementation for survival (e.g. Ceccarelli et al., 1995; Francis, 1989; Mitsch et al., 2001; Shiva, 1996).

A logical conclusion to such publicity might be that public funding for “modern” crop production research (including plant breeding) is not needed or even desirable. (Note: today’s most prevalent methods of “modern” crop production are also characterized with adjectives such as “intensive”, “industrial”, or “high yield”.)

Public distaste for private sector plant breeding

More or less concomitant with the increase in amount of commercial plant breeding, influential organizations and individuals with strong interest in right society and right environment have evinced growing distrust and dislike of commercial plant breeding, especially when it utilizes biotechnology as an aid in breeding.

To breed and sell seeds for profit is equated with disregard for social justice and environmental wellbeing. Evidence for such is that the seed companies (often called “multinational corporations” or “the biotechnology industry”) use patents and other forms of intellectual property rights to maintain control of the products of their breeding (“patents on life”), they use biotechnology (interpreted as synonymous with production of transgenic cultivars that by nature are dangerous to health and the environment, e.g., “Frankenfoods” and “superweeds”), and the current wave of purchases and consolidations in the seed industry foretells a time of complete monopoly or oligopoly in our global food systems, of self-interested corporate control of our food supplies (Benbrook, 2002; Charles, 2001; Fowler and Mooney, 1990; Jordan, 2000; Mooney, 1979; RAFI, 1994; Rhoades, 1991; Sorenson and Tufenkian, 1999).

Public distrust of biotechnology and the consequences thereof

The concerns of some people about biotechnology applied to crop plants have led them to doubt the utility or safety of plant breeding of any kind. The logical progression for this belief is as follows:

As noted above, the use biotechnology for plant breeding is considered by concerned individuals to be synonymous with production of transgenic cultivars, and they believe that transgenic cultivars are inherently dangerous to health and the environment. It follows that the use of biotechnology for breeding of crop plants is harmful, either now or at least potentially.

Significant numbers of people also believe that plant breeding can be accomplished only by use of “biotechnology,” probably because their first and perhaps only acquaintance with the name “plant breeding” was in connection with its interactions with “biotechnology.”

Therefore, if crop breeding is done only with biotechnology, and if biotechnology for plants is potentially harmful, it follows that plant breeding of any kind, public or private, is at best worrisome, and probably dangerous.

Evidence for this strongly held belief on the part of forceful sectors of the public is as follows:

> Recently, in the state of Washington, usually known for its progressive policies, strawberry plots and greenhouses belonging to Washington State University have been savaged, even though they contained not one single transgenic plant! In fact, nobody at that university has ever conducted transgenic research on strawberries (p. 122, Lurquin, 2001).

Effect of Funding Shortages

In the public sector

In recent years plant breeders in the U.S. land-grant universities have had to use research grants to replace the funds no longer available from state legislatures (Perry, 2000). Whereas the state funding supported long-term research such as that needed for successful plant breeding programs, the research grants typically provide funds for only a few years, and additionally they tend to support only currently fashionable “leading-edge” research topics rather than routine non-glamorous plant breeding programs. It is increasingly difficult for breeders to support an on-going straightforward plant breeding program.

A further consequence of dwindling funds is that university policies have moved strongly toward obtaining patents or other kinds of intellectual property rights for all possible “life-science” inventions made by their faculty (e.g. Pins, 1996). The universities intend to collect royalties when or if the patents are licensed to industry, and to use these royalties to supplement their constantly reduced funds from state and federal sources. Typically, royalties are to be shared between the inventor (i.e., the plant breeder) and the university (Parker et al., 1998).

This practice can reduce openness and collaboration among breeders, because of the legal need to prevent a patentable idea or germplasm from becoming public knowledge before patent application is made.

Both of these changes, to short-term funding and to emphasis on production of patentable products, have the potential to reduce the efficiency and the productivity of public sector plant breeding. Administrators and breeders alike can find ways to overcome these obstacles and to maintain the traditional public sector goals but it will take time as well as firm intent to do so.

One further change in funding sources makes the public sector behave more like the private sector. Check-off funds (as for wheat breeding) at times support substantial portions of public sector plant breeding operations in U.S. land-grant universities. Thus, the farmer, rather than the general public, supports the breeding activities, even though public funds still support the breeder’s salary (William F. Tracy, University of Wisconsin-Madison, private communication, 2003). To the extent that no other public funding sources are available, the scope of operations of the public sector breeder may be reduced, while at the same time such funding ensures close response of the public sector breeder to the needs and wants of the farmer who pays the check-off. As noted earlier, narrowed scope and tight farmer control of breeding goals are characteristic traits of private sector plant breeding.

In the private sector

Private sector plant breeding has not suffered funding shortages like those described for public plant breeding but funding shortages of another kind were brought on when biotechnology was added to the commercial plant breeders' toolkit. Companies had to spend large sums of money to set up and operate new laboratories, hire new personnel, and then to conduct multitudinous and elaborate tests of safety of newly produced transgenic products. Small companies could not raise the capital nor generate sufficient income to finance this research. As a consequence they would license products (if available) from the larger firms, or would out-source some of the needed work.

A different consequence ensued as well. Firms that were engaged in other types of agribusiness activity (such as manufacture and sale of herbicides or pesticides) purchased on-going plant breeding companies, often more than one, believing that biotechnology-aided plant breeding would be much more profitable than traditional commercial plant breeding had been (Pray and Naseem, 2003). They expected to make their new purchases into a highly profitable supplement to their current on-going business operations.

The net result of these two trends was (1) to reduce the number of independent plant breeding companies (they became subsidiaries of larger companies), and (2) to tie competitive agribusiness companies together in unusual ways via cross-licensing of transgenic products (for example) that were then used in a diversity of cultivars as sold by the competing seed companies (e.g. Fitzgerald, 2003). The plant breeding industry took on a new form, at least it seemed so to outside observers.

In reality, the number of seed companies and the distribution of their size classes may not be greatly different than they were twenty or thirty years earlier. In regard to maize, for example (which is still the chief income earner for most seed companies) a few companies (seven) with nation-wide sales accounted for approximately two-thirds of seed corn sales and a large number of small local companies accounted for the remainder, according to reports from the 1970s and 1980s (Duvick, 1984b). Private surveys indicate a similar distribution today, although names and ownership of the companies are different, and seem to be constantly changing. (But the present may or may not predict the future.) And the use of a single proprietary transgenic event in multiple and competing hybrids can be compared to the widespread use of a single public inbred (such as B73) in multiple and competing hybrids in earlier years, when top-performing publicly bred inbred lines of maize were available for use by all (Duvick, 1984a). The small seed companies in particular depended on public inbred lines to supplement the relatively small number of inbreds they were able to produce on their own. But a major difference of course is that the public inbreds were available for use without charge.

So Here We Stand —

Support for public sector plant breeding declines while the need for public sector plant breeding rises. In addition to its important role in breeding of major crop plants in places not adequately served by the private sector, public sector plant breeding is uniquely needed to:

- Educate and train future plant breeders
- Provide breeding products and collaborative assistance for impoverished farmers of the developing world
- Develop cultivars of minor crops and for niche environments
- Develop cultivars that can help to increase environmental health and biodiversity
- Investigate new and chancy research areas that could greatly aid plant breeding of the future

Few or none of these essential tasks are likely to be accomplished by the private sector. The need for public sector plant breeding is great and arguably has never been greater.

What can we do?

The question remains, how to stimulate public appreciation of and willingness to pay for these essential undertakings by public sector plant breeders?

The next two billion

Certainly it is important to publicize the absolute need for more food to feed the growing population of the developing world during at least the next two or three decades (Crosson and Anderson, 1992; Evans, 1998; Rosegrant et al., 2001). World population is predicted to increase by as much as two billion people during this period (IFPRI, 2002).

Calculations about adequacy of food supplies today (if they were fairly distributed) do not prove that we will be able to feed an additional two billion people by 2030. We must be concerned about how and if food supplies can be increased for the future, as well as about how they should be distributed today (or tomorrow). If global food supplies are inadequate in future years, a just and equitable distribution of them will ensure that all will be equally malnourished but that is not a desirable outcome.

We also must be concerned about consequences to food demand if (as one hopes) economies improve in the poorer countries of the world. Should this occur, their preferred diets inevitably would change towards higher proportions of meat and milk, foods that require more cropland area than do diets composed primarily of grains and legumes, and/or root crops (IFPRI, 2002). As noted earlier, the poorer countries of the world will provide most of the extra mouths to feed during the next few decades and so a globally improved economy will amplify the already large food demands of the additional two billion.

Plant breeding works

Likewise, it is important to point out that of the three important methods to ensure food for all (birth control, just and equitable sharing, and increase in yield per unit area), only the last method (which depends in large part on plant breeding) has worked to date, globally speaking. It would be irresponsible to not use our capabilities to increase food production further, in hopes that society worldwide will soon become more just and equitable or will universally practice birth control as needed to control population size.

As we strive to reach the goals of social justice and birth control, we can and must continue to increase food supplies, and even if the supplies are not distributed fairly, the poor will have at least some food to eat while we struggle to make the world better for them.

Spare land for nature; feed the poor

Increases in food production from now on must come primarily from increases in yield per unit area, rather than from transformation of wilderness into farmland, as has been done for the past 10,000 years. We are nearly out of unconverted land, worldwide, and our few remaining areas of wilderness must be preserved for their riches in biodiversity, their aid in control of global climate change, and similar environmental benefits (Crosson and Anderson, 1992; Evans, 1998; Rosegrant et al., 2001; Waggoner, 1994).

Plant breeding and improved management practices share the burden for yield increase in more or less equal amounts (e.g. Coffman and Bates, 1993; Duvick and Cassman, 1999). Ergo, plant breeding will be an essential part of the complex mix of socio-economic operations required to feed a burgeoning world population in ecologically sustainable fashion in the decades to come.

And because much of the increase in yield per unit area must take place in the developing world, where public sector breeding carries the load (especially for the rural poor), public sector plant breeding carries a heavy responsibility for feeding the world in the foreseeable future (Evenson and Gollin, 2003).

Improve nutrition and food safety

Not only more food but also more nutritious food is needed now and will be needed even more in the future. This is true especially for the poorest segment of the world's population, those with restricted opportunity to buy or grow a diversity of foods to provide a well-balanced diet. Plant breeding can be used to improve the nutritional content of staple food crops as well as to improve the yield and profitability of other crops able to provide useful dietary supplements (e.g. Busch et al., 1994; Ye et al., 2000).

And breeding for improved resistance to insect and disease attack gives the side benefit of food with fewer mycotoxins. Cultivars with increased resistance to insect and disease attack will make sounder grain, tubers, or whichever organ is used for food and so will be less likely to have invasion of fungi with associated mycotoxins (e.g. CAST, 2003; Rudd et al., 2001).

Thus, plant breeding helps to improve nutrition and food safety, and public sector breeding will be the indispensable tool to make such needed improvements for crops and markets not served by the private sector.

Help the environment

Perhaps another necessary task would be to show the influential public how modern cultivars can be more rather than less environmentally friendly, in particular with regard to their needs for fertilizer and pesticides.

Contrary to belief in some circles, successful new cultivars are more rather than less efficient than the old ones in utilization of fertilizer (whether organic or synthetic) (Hasegawa, 2003; McCullough et al., 1994; Ortiz-Monasteriao R. et al., 1997; Tollenaar and Aguilera, 1992). And they are more rather than less resistant to attack of locally important disease and insect pests (e.g. Kawano, 2003; Large, 1962; Rudd et al., 2001; Seiler, 1992; Simmonds, 1991; Smale et al., 1998; Walker, 1966)

Such knowledge might serve to increase (or establish for the first time) the general public's understanding of how environmental wellbeing can be aided by "modern" plant breeding and thus by the work of professional plant breeders in the public sector.

Think holistically; understand the system

A final and perhaps the most difficult task would be to tell concerned individuals and organizations — in words they can understand — how public sector and private sector plant breeding complement each other as part of the global system of food production, each contributing essential and sometimes unique products (improved cultivars, improved breeding knowledge and wisdom, improved germplasm pools, etc.) that the world needs and wants. Their products are often delivered to different clients with different requirements, or sometimes to the same clients.

Public sector: indispensable part of the whole

Most important of all would be to explain to the opinion-makers of the world that the two sectors need each other, that neither sector can carry the entire load, that neither of the sectors is inherently unethical or immoral, and that the best way to help either sector will be to understand and appropriately support both sectors as they continue to evolve their organization and technologies to fit a constantly changing world.

Tell the world

Such understanding could inspire the opinion-makers of the world to do their part to increase support for public sector plant breeding as it works to perform its vital and unique part of the plant breeding mission, to help feed the world in sustainable and equitable fashion.

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Table 1. Scientist Years, 1994, USA[a]

Crop	Public Sector	Private Sector	Total
Maize	35	510	545
Soybeans	55	101	156
Cotton	33	103	136
Wheat	77	54	131
Forage	71	51	122
Sorghum	15	41	56
Potatoes	41	9	50
Rice	20	22	42

[a]Source: Heisey et al. (2001)

Table 2. Area planted to private sector crop cultivars[a]

Region	Maize %	Wheat %	Soybean %	Rice %
World	43	9	45-75	<1
Developing	27	3	30-60	<1
Industrialized	99	27	70-90	?

[a]Paul Heisey (ERS) Provisional Estimate (2003)

The Current State of Plant Breeding: How did we get here?

Donald N. Duvick

The first crop breeders

- 10,000 years of plant breeding
- Wheat in southwestern Asia
- Rice in eastern Asia
- Bananas in Melanesia
- Maize in Mesoamerica
- Potatoes in South American Andes

How did they do it?

- Selection in variable populations
- Natural outcrosses including interspecific and intergeneric hybrids
- Mutations, including transposon systems
- Carrying cultivars to new lands instituted new selection pressures, gave rise to new cultivars with new adaptations
- Developing new tastes and uses gave rise to new kinds of selection pressure

Breughel The Harvesters c.1540

Modern plant breeding: "Scientific" & "Professional"

- Inspired by knowledge of functions of flower parts (19th century)
- Inspired by rediscovery and development of Mendelian genetics (early 20th century)
- Aided by development of statistics for analysis and design of experiments, trials
- But also depended on empiricism and intuition, as in the previous 10,000 years

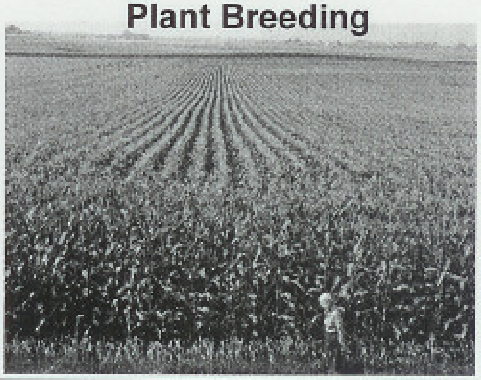
Professional Plant Breeding in the Early Years: 1900 - 1950

- Public sector breeding (public goods for the public good)
  - Universities
  - Government agencies, institutes
- Private sector breeding (private goods for the public good)
  - Horticultural crops (e.g., Burbank)
  - Open pollinated maize varieties, until ca. 1930
  - Hybrid maize, after ca. 1920

Professional Plant Breeding in the Early Years: 1900 - 1950

- Public sector is relatively well funded
- Private and public sectors interact closely, with public sector the acknowledged senior partner
- Public sector the only source of breeding for all field crops but maize in the US

One Product of Professional Plant Breeding



Professional Plant Breeding in Recent Times (1950+)

- Plant breeding for smallholders of developing countries initiated
  - National programs of newly independent nations
  - International research centers (CIMMT, IRRI and others)
- Private sector breeding of hybrid maize grows rapidly, especially in industrialized countries

Professional Plant Breeding in Recent Times (1950+)

- Private sector breeding of some self-pollinated crops grows rapidly in industrialized countries, following implementation of PVP and patents for biological materials,
- Sharp decline in farm numbers and growth of agricultural surpluses parallels (or initiates?) a decline in public interest and funding for agricultural research (including plant breeding) in industrialized countries.

Participatory Plant Breeding; A new old concept

- Breeding techniques suited for commercial agriculture in industrial countries can work also for commercial agriculture in developing countries
- ***But*** many farming people (2 billion?) in "traditional agricultural areas" (poor land, poor economy) do not farm commercially and have different and highly diverse needs for variety improvement.
- ***Participatory plant breeding*** may be best suited for such "traditional" farmers

Participatory Plant Breeding

- Participatory plant breeding has several variations, all emphasize
  - decentralization
  - strong farmer participation
  - on-farm testing
- Professional breeders from public sector *advise* but do not *dictate*
- Goal is to produce varieties that
  - meet local farmers' needs
  - that farmers can reproduce

Plant Breeding Today: Division of Responsibilities

- Public sector plant breeding
  - Breeders are employed by public institutions (public universities, government agencies)
  - The public pays the bills (taxes)
- Private sector plant breeding
  - Breeders are employed by seed companies
  - Farmers pay the bills (seed purchase)
- CGIAR Centers plant breeding
  - Breeders are employed by international centers (CIMMYT, IRRI, IITA, etc.)
  - The public pays the bills (government, taxes)

Division of Responsibilities

- The three sectors depend upon each other
- All three sectors work for the same client: the farmer
  - and indirectly for the ultimate consumer
- Public sector and international centers have broadest mandate
  - To produce public goods wherever needed
- Farmers exercise greatest control over the private sector
  - "If I don't like it don't buy it."

Division of Responsibilities

- To some extent all segments do the same things, but each has its own specialties:
- **Public sector**
  - Universities: basic and applied research, education
  - Government agencies: basic and applied research, germplasm conservation
- **CG centers**:
  - product development and delivery to smallholders of developing countries worldwide
- **Seed companies**:
  - product development and delivery to commercial farmers worldwide

Scientist Years, 1994, USA

(Source: Heisey 2000)

Crop	Public Sector	Private Sector	Total
Maize	35	510	545
Soybeans	55	101	156
Cotton +	33	103	136
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Potatoes	41	9	50
Rice	20	22	42

Seed Companies: Global Impact

Area Planted to Private Sector Crop Varieties

Source: Paul Heisey (ERS) Provisional estimate, 2003

Region	Maize %	Wheat %	Soybean %	Rice %
World	43	9	45-75	<1
Developing	27	3	30-60	<1
Eastern Europe	<5	<1	<1	<1
Industrialized	99	27	70-90	?

Global Trends

- Public sector funds for plant breeding, level to declining, especially from states
- CG funds for plant breeding, declining, especially for core research
- Private sector funds for plant breeding, increasing annually, especially for biotech
- Farmer selection/breeding still essential in parts of developing world
  - In countries with social/economic chaos
  - For non-commercial crops (e.g., oca, cassava, yam)

Global Trends

- New technologies impact professional plant breeding
  - Mechanization
  - Computers
  - Biotechnology
- Plant breeding increasingly costs more per unit of gain
- Public sector's applied research is still essential for minor crops and niche crops
  - But funding doesn't follow needs

Global Trends

- Public distrust of and distaste for commercial agriculture
  - Modern food production technologies = environmental disaster
  - Resulting reductions in public support (and funds) for agricultural research including plant breeding

Global Trends

- Public distrust of and distaste for commercial plant breeding
  - Profit motive = disregard for social justice and/or environmental well-being
    - Intellectual property rights (patents, etc.)
    - Biotechnology (Frankenfoods, Terminator)
    - Concentration of seed companies = monopoly control
  - Resulting activist operations to reduce and/or eliminate private sector plant breeding

Global Trends

- Public distrust of and distaste for biotechnology applied to plant breeding
  - Biotechnology = transgenic organisms
  - Transgenic organisms = dangers to health and environment
  - Plant breeding = Biotechnology
  - Therefore plant breeding is bad — both public and private
    - Fire destruction of U of MN laboratories
    - Fire destruction of WSU laboratories
    - Vandalism of Pioneer Hi-Bred breeding stations

Global Trends

- *Public sector*: Need for funds drives plant breeding toward short term goals:
  - Grants to replace state money. These usually reward only short term accomplishments (e.g., 3-year terms)
  - Patentable products, to earn royalties for researcher and university
- *Private sector*: Need for funds to do biotechnology and/or an expectation of riches from use of biotechnology in plant breeding drives consolidation/buyouts by non-seed companies

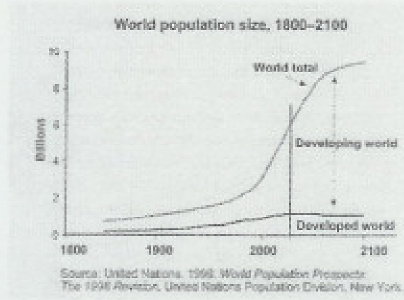
Sample Quotes
(and a few graphs)

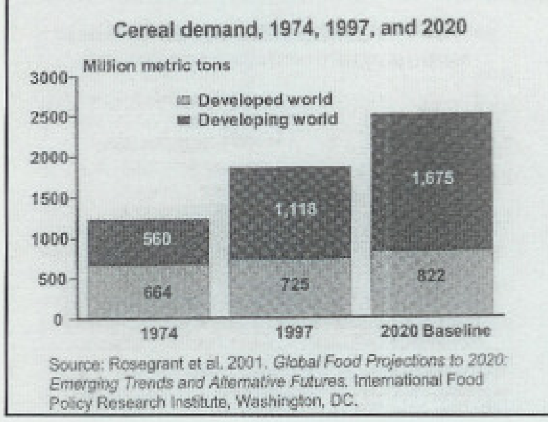
- Higher yields not needed
- Funding declines
- Gains cost more
- Parasite or protector?
- Plant breeding = genetic engineering?

Higher yields not needed

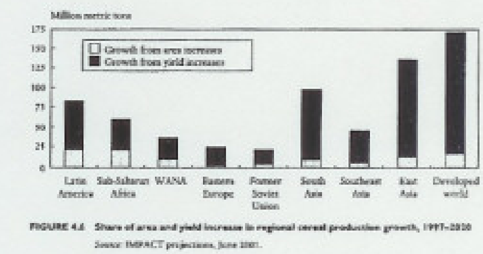
- "The biotechnology industry claims it holds the answer to world hunger: *high technology to increase production.* But according to the United Nations Food and Agriculture Organization (FAO), this badly misstates the problem. There is no shortage of food in the world. Per capita food production has never been higher."
Advertisement in New York Times, October 11, 1999, by *Turning Point Project, a coalition of more than 60 non-profit organizations.*

Global Population Trends



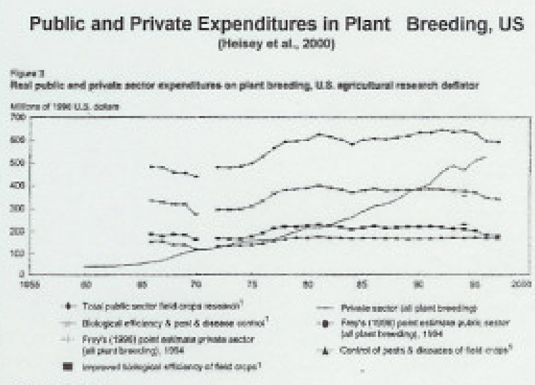


Cereal Predictions: Area vs. Yield



Funding declines

- "Expenditures on agricultural research in the public sector, including the International Agricultural Research Centers (IARCs) have stagnated and in some cases, declined sharply in recent years." (Maredia and Byerlee, Agricultural Economics 22:1-16. 2000)



Gains cost more

- "… the [annual] percent gain in grain yield (the rate of gain) is declining and has declined from the beginning of this time-series. Unfortunately, the cost per unit gain has not declined. … The cost per unit of yield gain has risen continually in past years and it probably will continue to increase unless new efficiencies in breeding are introduced."
Duvick et al., (2004) *Long-term selection in a commercial hybrid maize breeding program*, in Plant Breeding Reviews Vol. 24 (in press).

Parasite or protector?

- "… government does the costly, basic and innovative research, while big companies pick up the profits in the marketplace." (Fowler and Mooney, "*Shattering: Food Politics, and the Loss of Genetic Diversity*". *1990.*"
- "Some question the need for continued public funding [of agricultural research], thinking that … the private sector will do the job." (Pardey and Beintema, *Slow Magic.* IFPRI Policy Statement. 2002)

Plant breeding = genetic engineering?

- "Recently, in the state of Washington, usually known for its progressive policies, strawberry plots and greenhouses belonging to Washington State University have been savaged, even though they contained not one single transgenic plant! In fact, nobody at that university has ever conducted transgenic research on strawberries." (Lurquin, *The Green Phoenix, A History of Genetically Modified Organisms.* 2001)

So, here we stand

- Support for public sector plant breeding declines
- Need for public sector plant breeding increases,
  - Especially to educate and train new breeders
  - Especially in developing world
  - Especially for minor crops and niche crops
  - Especially for crops that can aid in increasing environmental health and biodiversity
  - Especially for investigating new and chancy research areas that might aid plant breeding

A Farmer's Perspective on the Current State of Plant Breeding

Response to Keynote 2: The Current State of Breeding -How Did We Get Here? Dr. Don Duvick

Paul Johnson
Rolling Prairie Farmers Alliance, Kansas, pdjohnson@rnworks.com

Thank you for this opportunity to respond. This is a very learned crowd on public breeding and I am still on a sharp learning curve. I come here as a farmer and a family farm public policy advocate. I came to Washington on Friday to talk to USDA officials and staff members of Congress on sustainable farming research and conservation programs being developed out of the 2002 Farm Bill.

As a farmer I am finishing my 10th season with the Rolling Prairie Farmers Alliance. Rolling Prairie is a co-operative vegetable subscription service that sells produce weekly to 330 households in the Lawrence/Kansas City area. There are 8 growers in Rolling Prairie and we sell from mid-May to October.

During the winter I work as a fulltime legislative advocate for several churches in Kansas. I started in 1981 on poverty issues and today I split my time between poverty and family farm issues. The Kansas Catholic Conference supports my work and I have written and edited two Agriculture White Papers sent to all Kansas policymakers. The Most Reverend Ronald Gilmore, the Bishop from Dodge City, Kansas is now the chair of the agriculture and trade subcommittee for the United States Conference of Catholic Bishops (USCCB) that is now updating their official position from 1989 on agriculture and trade. The issue of public breeding and genetically modified organisms is addressed in this paper. It questions the control of the seed industry by few firms and supports going very slowly with the adoption of GMOs. This issue is resonating in many forums.

Over the last few years, I have served on a steering committee for the Kansas Family Farmer Coalition. This Coalition is comprised of the Kansas Farmers Union, the Kansas NFO, the Kansas Rural Center, the Kansas Cattleman's Association, Kansas Ecumenical Ministries and several other groups. Last Wednesday, this Coalition formally met with our land grant university - Kansas State University (KSU). KSU is in the process of selecting a new Dean of Agriculture and adopting a five-year work plan for K-State Research & Extension. The future of farming is at a crossroads in Kansas and sustainable, family farms deserve a fair share.

The K-State Research & Extension budget is $100 million. $55 million of this comes from state government ($48 million) and federal formula funds ($7 million) while the rest comes from public grants ($43 million) and private grants ($2 million). K-State takes the state & federal block grants and spends over 90% on salaries and some overhead. In essence faculty is hired and told to raise their own grant money. The problem with this picture is that the type of sustainable agricultural research we want is not funded by grants. Despite our best efforts at a federal level to get USDA to fund more low-input, sustainable, alternative crop or forage research, USDA always has other priorities for its high-tech agenda.

Our Coalition came to K-State with specific research and extension requests. Kansas imports all of the food grade oats used in the state. Kansas needs to breed a food grade oat for our region and climatic conditions. For our organic wheat growers in Western Kansas, there needs to an alternative crop for rotations since organic[i] wheat can be produced just one out of every third year. Flax is such a crop that needs study. While Kansas has 20 million acres in perennial forage and 3-6 million acres in annual forage, there is very little research on extended grazing systems, alternative grazing crops or management intensive grazing trials. K-State finds the funds for confinement systems for hogs or dairy cattle but none for pasture based pork or grass based dairying.

In the last month KSU has announced the formation of Wildcat Genetics that will work with Monsanto to take KSU developed soybean varieties and insert roundup ready genes. KSU hopes to corner 20% of the 3 million soybean acres in Kansas. Can the development of round-up ready wheat from KSU be far behind? Where is the announcement of the public breeding done at KSU and do the farmers win if they have to pay tech fees for seed they can no longer save? There has been no public debate at KSU on these fundamental changes in patenting seeds - especially seeds that came from publicly funded research! The basic mission of the Land Grant system is to serve all farmers and provide basic public research that will not be done at any other institution. I guess I should not be surprised given that the new Director of Research at KSU spent the last 17 years at DuPont. Sustainable, low-input, alternative agriculture deserves a fair share - say 30% - of the public financing going into K-State Research & Extension.

These previous comments reflect the real world we are facing in Kansas to get a fair share of resources into public breeding and the dynamics of public policy. I do have several concerns regarding 'Crop Breeding in the 21st Century' by Donald N. Duvick. Overall though, this was a very thoughtful paper and lays a basis for a very necessary public and private debate on crop breeding.

Mr. Duvick assumes that the public sector will be the training ground for plant breeders. I would argue this only happens if we get a fair share of the public funding directed that way and that long-term basic research for plant breeding is prioritized. As he says " Public research in plant breeding has moved toward investigations that produce intellectual products (e.g., publications) rather than biological products (e.g., cultivars). An unfortunate consequence is that the public sector has fewer field-experienced breeders and, therefore, has less capacity to train field-breeders in the agricultural universities."

What needs to be more directly addressed is the patenting of seeds and organisms and what impact that will have on private versus public breeding work? How is it that public institutions can develop lines of regionally adapted seeds and watch that long-term investment patented with the insertion of one gene among thousands? If the private breeding sector takes over the commercial crops and seeks the largest return for the most widely used seed, what happens to niche markets such as high-protein open pollinated corn? The issue of patenting life and intellectual property rights must be a debate re-opened in Congress and the courts.

Dr. Duvick states that large number of small companies will provide cultivars for a significant share of the market and, thereby, hold back incipient tendencies toward monopoly or oligopoly. Well I hope so but recent events in the Midwest provide concern as 'pharmaceutical' field crops are not properly controlled by Prodigene and thousands of bushels of soybeans were destroyed. USDA had all of two inspectors for over 150 test fields in Kansas this year. Proper oversight and regulation has to be established. Who knows the risks these start-up companies may take trying to hit the jackpot gambling with our food supply?

Fundamentally are we headed for a have and have not system of plant breeding whereby private breeders will garner the greatest resources while public breeders and farmers will make do with far less? There are inherent public policy questions tied up with these decisions. Minor crops should not have to take a back seat. These crops along with regionally adapted major crops will be the key to a diversified and more secure food system. In a time of bio-security, local and regionally based food provides the greatest protection. This should be an integral part of our strategic food planning and funded accordingly!

To end these remarks on a most positive note - one remarkable victory in the 2002 Farm Bill was the Conservation Security Program (CSP). CSP is the first conservation program directed to working farms for specific stewardship activities and whole farm planning. One component of CSP can be seed saving and breeding. The rules and regulations are soon to be promulgated by USDA. It will be very important for sustainable farming and public breeding advocates to insist that breeding and seed saving be included as stewardship activities. In times of very tight budgets, redirecting conservation programs could well be our best hope to expand public breeding and educate the public on the long-term connections of conserving seeds, breeds and land.

Public vs. Private Plant Breeding for 21st Century Agriculture

Response to Keynote 2: The Current State of Breeding - How Did We GetHere? By Don Duvick

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Introduction

Plant breeding was the basis of domestication of the wild plants that developed into the modern agricultural crops that we depend on for food today. The early plant breeders selected variants in their plots and fields that had more desirable features for cultivation than the wild progenitors. The increased productivity of crops meant that fewer people could produce more food with less effort. This led to an increase in the amount of time individuals, and societies, were able to spend on activities other than food procurement, and as such, allowed time to be spent on developing technologies that made food production even more efficient. Relieving some members of the society from food production activities entirely allowed them to focus on other areas of technology and social activity that has evolved into the current complex interdependent societies that we all now live in. Thus agriculture in general, and plant breeding specifically, and are the roots of modern civilization, and continue to be the basis of food production around the world.

Role and Tradition of Public Plant Breeding

The early farmers developed and maintained their own varieties and land races. With the discovery of Mendel's paper on trait inheritance in peas in 1900, the era of the professional breeder using the tools of genetics began. The public sector plant breeder has been the traditional source of new, improved varieties of field crops for most farmers. The varieties developed in the public sector, through federal agencies and/or state- and provincially-supported universities, have been considered to be publicly available for unrestricted multiplication and commercial production by farmers. Many states have a Foundation Seed Association that is responsible for the purification and initial increases of new varieties, and for the release of pure seed to farmers for further multiplication, distribution, and commercial production. In Canada, the Canadian Seed Growers' Association performs the same functions, as well as administering the pedigree seed production system as mandated by the Canada Seeds Act.

Public breeders have been at the forefront of significant improvements in new varieties, such as developing better disease resistance in collaboration with the pathologists often located at the same institutions. Public breeders have also produced new and improved quality types, again in conjunction with the quality researchers at the same, or sister, public institutions. Improved agronomic types have also been developed by public breeders in association with the agronomic and production researchers, and with the collaboration of extension personnel in the field. Most of these improvements have been made to increase production and efficiency on the farm or in the processing plant.

Public researchers generally have the infrastructure and technical support to conduct basic science in underlying principles, or 'discovery research', in addition to applied research leading to specific products. This exploration of new ideas and theoretical concepts is usually conducted using graduate students who are being trained in research methodology and general scientific principles in the research program. Thus, the development of new technology and the education of new researchers and scientists are concurrent, and is traditionally the role of the public plant breeders.

The technology developed in the public sector has generally been considered to be 'public domain' with no restrictions on who could utilize it, and being widely available to anyone who wanted it without cost, since it was nominally developed at taxpayer's expense. This has changed in recent years with many public institutions applying for patents on publicly developed technology and collecting royalties on seed of publicly developed plant varieties. The returns from these technologies may be put back into the programs that generated them to increase the funding base for basic research. The additional revenues can be used to increase the potential to produce more commercially viable materials. The royalty returns may also be used to supplement/replace decreasing public funds, or they may be simply 'siphoned off' to support other totally unrelated activities. In some cases, the researchers who contributed intellectually to the development of the technology may personally receive some of the returns from the commercialization of the technology. There are numerous models, and generally a bit of controversy around each one of them as to how the research was funded and the role of public institutions in commercialization of 'public' technologies. Who pays, and who gets paid? The question of the 'public good' is often overlooked in assessing the value of publicly-supported research.

Germplasm containing new disease resistance genes or new agronomic features developed by public breeders is often the backbone of modern varieties of even the most major crops. The private companies are relying on this germplasm as the source of desirable new materials in adapted backgrounds. In Europe, much of this public material is purified and marketed directly to farmers by private companies.

In some crops and some regions, publicly developed varieties are released to growers without restriction or obligation once the seed is purchased. This usually results in wide, rapid dissemination of new varieties. In other regions, due to the maturity of the seed industry, varieties from public institutions may be released exclusively to specific companies for multiplication and marketing. This allows a company to supply additional specific information about a variety, and encourages more effort in the promotion of a specific variety and, potentially, faster and more widespread availability to farmers.

Research in breeding methods/techniques has been, and continues to be, conducted almost exclusively in the public sector. The results of such research are reported in scientific journals for evaluation and potential adoption and adaptation by all breeders, both public and private. Such research may be conducted by private companies, but is not reported in scientific journals where it could be used to advantage by competing companies. Technique application and modification has been done in private companies, but the science and theory behind many techniques, such as haploidy in several crops, single seed descent, and many molecular marker technologies, has often been developed by public researchers.

While the public sector has generally been charged with conducting discovery research, educating students in general science and research methods, and producing products that may not have a great deal of commercial potential, the private sector has usually been applying the science and technology in product development and in marketing products with the objective (and clear intention) of realizing a profit. There has been a gradual convergence of these two roles in recent years as research and educational institutions have been taking a shorter-term approach to projects and have been collaborating with private industry on developing specific products that have significant commercial potential (often with matching funding from various levels of government).

Public institutions have recently been cast in the role of competitors with private plant breeding companies by getting into the marketing business through commercialization arrangements with specific private companies. This often leads to a conflict between the longer-term, exploratory research that has no immediate nor obvious application vs. shorter-term, focussed research which has commercialization rather than science as the main objective. There is probably a desirable balance between the two, but administrators generally see much more benefit in commercially viable results (and profits) than in advancing scientific knowledge.

In a number of minor crops, particularly horticultural crops, public breeding may be the only source of new varieties, although some private companies may increase and distribute seed on an exclusive basis. In some regions, where certain crops that may be prominent on a world-wide basis have a limited production potential, public programs may also be the sole/primary source of adapted material for farmers. These are often significant markets on a regional basis, but the economic returns are not great enough to stimulate private investment in breeding.

There is occasionally a resentment of the public breeders, with their taxpayer-funded programs and vast public support networks, by the private breeding companies which must operate exclusively on income generated through seed sales, and also turn a profit for their shareholders. Often the public programs have been in place for a long time and the private breeding company is a newcomer to the game.

Development of Private Plant Breeding

The development of private plant breeding began many years ago and is well-established in a number of crops. The advent of hybrid corn created an opportunity for private industry to become involved in supplying varieties directly to farmers with the assurance that farmers would not be able to multiply the seed indefinitely for their own use and for further distribution to other farmers. By being able to 'protect' the germplasm used in seed production, there was considerable potential for profit, and many modern plant breeding companies have evolved from older hybrid seed corn companies.

Private companies developed in Europe in many self-pollinated crops where intellectual property rights and plant breeder's rights have been in place for much longer than in North America. The collection of royalties on the first, and occasionally subsequent, generations of seed from self-pollinated crops has made them profitable for private breeding companies. The level of competition among companies has stimulated the development of numerous crop improvements that have benefited the farmer as well.

The public institutions in Europe have generally not been involved in directly releasing finished varieties to the farmers for commercial production. Early generation material from public programs is usually released to private breeding companies where final purification and evaluations are conducted. The finished product is released by the private breeding company which collects a royalty on seed sales. Whether a portion of the royalty goes back to the public institution varies with the institutions and with the arrangements they have with the companies. In some cases the identity of the originating institution is recognized by the company, but in many cases it is not acknowledged publicly. The public institutions are not only doing the basic research in methodology and technology, but also supplying the basic germplasm and improved breeding lines leading directly to varieties. The philosophy is that it is generally in the public's best interest to work closely with private industry to ensure that the publicly-developed technology is ultimately made available to farmers, and that the society at large is benefiting from this material being available (at a price) through the private sector. The private sector is generally considered to be more efficient at multiplication, promotion, and marketing of seed technologies than public institutions.

There is a significant philosophical issue that needs to be addressed by politicians and administrators of public institutions: is public plant breeding a desirable (or necessary) service to society, or is it a public research subsidy to the multinational corporations that own most private plant breeding companies? If public plant breeding contributes significantly to the public good though development of more efficient breeding techniques and technologies, through training the breeders who work in private industry, and through release of improved germplasm to private industry and new varieties directly to farmers, then it is not necessary to consider generating a direct return on the public investment that funds such programs. Public plant breeding would then be deemed to have intrinsic value *per se*.

If, on the other hand, the main beneficiaries of public plant breeding research, training, and germplasm development are multinational corporations which use this benefit in other parts of the world whose farmers are in direct competition with farmers who are funding the institution providing that benefit through taxes, then the question of whether that service should continue to be provided should be seriously questioned. Recovery of [some of] the costs of research, training, and germplasm development from private industry should then, perhaps, be a consideration by administrators.

This is an issue that needs public debate and political resolution at the highest levels as it is related to the issue of food security and basic agricultural policy.

The Next Generation of Public Plant Breeders

A significant, and almost exclusive, role for public institutions has been educating plant breeders to work in both public and private breeding programs. As an increasing proportion of the bright young plant breeders go into private industry, and as more public breeding programs get cut back or eliminated completely, the 'environment' for educating and training the plant breeders is getting seriously eroded. The question is often asked as to whether a full-scale breeding program with the critical germplasm mass, technical support and costly infrastructure necessary to develop competitive commercial varieties is necessary in educating and training a new plant breeder. The amount of experience necessary for a young breeder to be able to conduct and manage a commercially viable breeding program is often debated among breeders and among those involved in educating breeders. Because of the applied nature of plant breeding and the broad scientific basis of breeding, an exposure to the basic theory of evolution and genetics in not enough. An understanding (and appreciation) of the role of environment, agronomy, pathology, biochemistry, statistics, botany, physiology, soil chemistry, molecular biology, modern mechanization, and financial and personnel management in conducting a breeding program are necessary, as is actual field experience in population management and selection. With the down-sizing of public-sector plant breeding programs in general, and the focus on more short-term applied objectives and biotechnology research, the ability to educate young plant breeders appropriately and adequately is becoming a concern at a number of institutions.

There is usually less of a problem with the theoretical side and a bigger problem in getting the practical exposure that is considered to be essential by most practicing plant breeders. Perhaps a hybrid program where the university provides the classroom teaching in the theoretical aspects of plant breeding should be combined with a commercial breeding company providing the field experience in a more collaborative approach to educating and training the breeders of the future (Duvick, 2002).

A further concern that I have as a professor of plant breeding is: *who is going to be teaching the plant breeders of the future and where are these teachers being educated today*? The depth that most of the professors currently teaching plant breeding obtained during their graduate studies is not there in most current university graduate programs. The basic background of most currently teaching plant breeding professors has been in botany, agronomy, and Mendelian or quantitative genetics, whereas most of the students being trained in breeding today have a background in molecular genetics and are missing the classical botany and practical agronomy training. Understanding the multitude of factors, particularly environmental, that interact with the genotype in determining the phenotype of a plant requires a solid background in many different disciplines related to biology.

With more emphasis on getting students through in a shorter time, there is less chance to take the wide range of courses needed to get the broad background training in supporting disciplines that a breeder uses in many aspects of the daily operation of a program designed to improve the performance of a crop.

Farmer Participatory Plant Breeding

There has been a recent trend toward promoting 'farmer participatory plant breeding'. This concept is based on the assumption that farmers, with their intimate association with the daily growth and development of their crops, are able to identify the 'best' phenotype for their environment in a heterogeneous population of plants (i.e. selection). The fact that most modern varieties are descended directly from land races that were developed by farmers over the past several thousand years is also used to support the premise that farmers are quite capable plant breeders. It is generally acknowledged that farmers do know good plants when they see them.

Modern, mechanized farming is much different from the conditions in which our ancestors were planting, cultivating, harvesting, and processing their crops by hand. Ancient farmers were much more aware of individual plants and more appreciative of the variation among plants than farmers are today when most operations are conducted from a heated/air conditioned tractor cab with a stereo and tinted glass. Modern farmers seldom look at a single plant because they are too busy looking after the vast fields of them.

Although farmers may recognize desirable plants, they generally do not have the facilities, equipment and technical expertise to evaluate such selections to validate their true worth. Plant breeders usually spend most of their resources in the evaluation phase of the breeding program. This involves large numbers of small plots and utilizes specialized equipment, sophisticated statistical designs and field plot techniques, and highly developed computer software in analyzing the results. This is generally beyond the resources and technical capabilities of most farmers.

Professional plant breeders have access to a wide range of germplasm and the facilities that are needed to generate the genetically variable populations that are used in producing superior genotypes that possess all the desired agronomic, disease resistance and quality characteristics needed in modern varieties of crop plants. Plant breeders also have the facilities and technical support needed for multiplying the seed up from a single plant to the amount needed to evaluate a genotype in replicated small plot trials. These seed quantities are much less than most farmers can handle in commercial sowing and harvesting equipment. Thus, there are several aspects of breeding that modern farmers are not necessarily going to be able to carry out as effectively as their ancestors did.

Modern plant breeders are well-trained and well-equipped specifically to address the creation of variation in a population, the growing of highly heterogeneous populations in environments where critical differences among individuals can be easily seen, and the evaluation of small plots for the numerous essential factors necessary in a modern variety. A partnership between farmers and plant breeders where some of the selection is done by farmers and some of the evaluation is done on farmer's land while the crossing and the bulk of the evaluation is done by breeders, would seem to be the most workable model. To succeed, it has to be functional and practical. There may be very different approaches in developed vs. developing countries and in areas with different agronomic potential and needs.

Many modern plant breeding companies have evolved from small cooperatives of farmers trying to obtain good quality seed of desirable varieties. The successful cooperatives grew and expanded from simple seed purification and multiplication to include development of new varieties, in addition to the functions. The Svalof-Weibulls breeding company in Sweden, which grew from the Swedish Seed Association cooperative, originally formed in 1886 is a good example of such an evolutionary sequence (Olsson, 1986)

With the development of modern technology, plant breeding has become a highly specialized and technical process of genetic manipulation and precise evaluation of a multitude of traits in a range of environments. A successful modern variety has considerable value to a farmer and to a seed company. The control of the seed of a variety (or other propagation material) is important to the continued profitability of a variety.

Summary

Plant breeding has evolved from gathering seeds in wild stands of food plants to the domestication and cultivation of the many crops which form the foundation of modern civilization. Plant breeding was very successfully practiced by ancient farmers who had an intimate association with their crops. Modern plant breeding has become a profession based on science and results in the production of new varieties of some crops that have considerable commercial value. The private sector has become increasingly involved in the development, production, promotion, and marketing of new crop technologies in the form of varieties which are protected with patents, contracts, plant breeders' rights, or other legal protection. The future of public plant breeding and the research and education functions associated with it are at risk in a societal environment that considers only profit to a commercial enterprise and not general benefits to society at large.

'A prepared mind is the best tool a breeder can have.'

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Remarks on the Occasion of the Seeds and Breeds Conference

Response to Keynote 2:The Current State of Breeding - How Did We Get Here? By Don Duvick

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Don Duvick has presented us with an excellent overview of the current state of crop breeding and his vision of crop breeding in the 21st century. His view of a tripartite system consisting of the public sector, the private sector, and participatory plant breeding among NGO-supported farmers holds great potential. But this potential is unlikely to be realized unless we see some fundamental shift in the current dominant economic paradigm.

The public commons is being systematically dismantled and converted into commodities by governments and trans-national corporations in order to drive a global economic system based on consumption.

In agriculture, this economic system drives us toward monoculture and petro-chemical based methods. It has also systematically displaced millions of people from the land.

But, you may say, economic globalization is inevitable and the loss of farmers and industry concentration we see is a natural consequence! Do you really believe this?

I believe we are trapped in a collective trance that holds us captive to this self-limiting view of reality and the human possibility. A trance that strips our lives of meaning, mocks compassion as being naïve, and gives only lip service to concern for the public domain, or the well-being of one another and the earth.

Our unwillingness or inability to imagine alternative systems is testimony to the power of this trance.

At some level, we know the truth is we are a multivalent treasure -- an infinite bundle of possibilities--an incredibly unique event in the 14.5 billion year history of the Universe. Differentiation is a cosmological imperative!

We have to awaken to the reality that we have given our lives over to the culture and institutions of a global corporate economy, what David Korten calls a suicide economy. This is an economy that rewards us for destroying life—the lives of people, community, and nature in exchange for money.

With our tacit or active support, governments, corporations and even land grant Universities are privatizing the commonwealth—our water, land, seeds, forest—for profit, while externalizing as many of the costs as possible, passing them on to communities, workers, and non-human species.

U. S. corporate profits are about $500 billion per year. Conservative estimates of externalized costs within the U. S. economy, including pollution, health and safety, crime, etc. comes to about $3 trillion a year.

Our whole political process has been warped to serve as a legal and economic tool for this privatization of the commons for profit and externalization of costs.

On top of all that, we're changing our lives, and those of other entities to fit our technology, rather than developing technology that fits our lives.

Monsanto doesn't ask, "How can we develop our chemicals to fit the crops you want to produce?" No, they genetically modify the crops to tolerate the chemical.

Of course, it's too simplistic to say that if we could stop transnational corporations or international trade, then we could develop ecological sustainability.

We are being called by the deep intelligence of creation to accept personal responsibility for the consequences of our presence on this planet,

The dominant paradigm is well secured against internal reform. It is vulnerable, however, to displacement through succession by emergent life-serving living systems attuned to the needs and well-being of mature and healthy human communities.

I believe we have to support the emergence of such life-affirming systems with broad-based public participation and ownership.

We have a responsibility to move from the current system, which is characterized by polarization and separation, toward union. I think of the word 'responsibility', the ability to respond—as plant and animal breeders, we have an obligation to increase the ability of the global biosystem to respond through diversity.

I am a beef cattle breeder of some notoriety, so I would like to give a little perspective on the current state of the cattle breeding sector. Most cattle breeding still occurs in the **private sector**. But this sector is characterized by increasing concentration and consolidation under the agri-business paradigm. While there are a small number of passionate, innovative breeders, most seedstock producers are replicators whose breeding decisions are based on single-trait selection for the industrial complex.

Breed associations such as the American Angus Association provide extensive statistical databases that are aggregated using linear regression models to develop tools for breed selection (expected progeny differences). These are generally used with little understanding and drive the kind of single-trait selection that so often results in the biologically unfit breeds mentioned earlier by Don.

AI studs, many of which have consolidated into rather large corporations themselves, compete to market the semen from expensive, highly promoted, and occasionally biologically unfit sires. Most of the seedstock industry (the replicators) rely on semen from these AI studs rather than independent thinking.

The **public sector** has been reduced mostly to 'research for hire' and therapeutic intervention. The research herds of the past have mostly disappeared due to lack of funding or interest. The few university owned herds that persist generally lack a public genetic focus and have poor continuity in management and vision. It has been many years since we could remark upon an innovative or useful new genetic line introduced in the cattle industry by the U. S. public sector.

Consistent with the 'ownership' of research by corporate interests, much of the research from these public programs has been focused on gross reductionist manipulation and development of tools for single trait selection (marbling gene, sexed semen, cloning). Sadly, little of this makes it into the public domain. Most of this research is privatized by the universities into corporate products and subsequently sold to ranchers for a profit.

The public sector continues to serve an educational role, though this is often uninspired and geared toward the needs of the industrial complex. I am encouraged by recent university efforts (most notably Colorado State University, Texas Tech, and Michigan State University) to partner with large ranches and conservation organizations to give students a more 'real world' exposure.

As seems to be the case in plant breeding, animal breeding in the public sector is being gradually dismantled or converted into 'research for hire' for corporate interests.

So where do we go from here? Biological science has to recognize what physics has known for years—we are all energy forms comprised of small amount of energy and vast storms of emptiness. We are not separate, we are not objective observers, we are participants in complex, dynamic, non-linear systems that are poorly understood and largely unpredictable. Our decisions do not exist in isolation from these interpenetrating systems. Consequently, how we act in regard to our biological systems becomes enormously important and, to quote Wendell Berry, “How we act in ignorance is paramount.”

Corporate or economic interests represent a devastatingly narrow parameter within which to define our public plant and animal genetic needs. Given the complexity and inter-relationship of our biological systems we have to recognize the extraordinary public trust implicit in maintaining our plant and breeding commons. As public plant and animal breeders, you are cultivating and protecting this commons—not only the genetic diversity represented thereof, but the deep wisdom and art associated with plant and animal breeding.

You are the keepers of a sacred public trust, not only as a result of your employment and your deep calling, but of your very consciousness. You have an obligation to defend this trust. But how? As we’ve noted throughout this meeting, plant and animal breeders are lovers, not fighters.

As lovers and breeders, you are familiar with unusual matings and cross-pollination. The good news is, we don’t exist in isolation and we know that the most successful biological systems are adaptive and collaborative.

Our strength lies in our ability to seek out new partners and unusual configurations of collaboration. We need to articulate our values, then look for momentum in areas of funding, policy, and public opinion that are consistent with those values. Where are our partners in such diverse areas as:

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- Open Source software development (Bio-linux concept),
- Sustainable agriculture,
- Land trusts,
- Farm organizations,
- Wildlife advocates,
- Hunting advocates,
- Environmental organizations,
- Systems and complexity science?

We need to focus on breeding **systems** of interconnected plants and animals that are ecologically and economically sustainable and readily available to the public. I’m always struck by the effectiveness of the model the ZERI organization has used in third-world countries. For instance, they might take an unprofitable monoculture coffee farm in which 99.2% of the biomass produced goes into the environment as waste, and convert it into a complex, profitable five enterprise system producing coffee, methane, mushrooms, chickens, and cattle feed.

The potential for developing these complex systems of agriculture has profound social, economic, and ecological implications.

And, of course, it’s not just about food. These systems can support such diverse public needs as biofuels, paper pulp replacement, medicinal herbs, polyculture production, biodigesters, fungus, algae, and more. Viewed in this manner, public plant and animal breeding can make tremendous contributions toward addressing major social and cultural problems.

If we are going to effectively change the current system, we must have an emergent identity around which our values and consciousness can cohere. If we hold this common vision in our intention and consciousness, we will manifest it in our physical reality.

Keynote 3

Responses

Keynote 3: A System Out Of Balance - The Privatization Of The Land Grant University Breeding Programs

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The Bayh-Dole Act of 1980 paved the way for commercialization of public research programs. Included in the Act is the stipulation that the "inventor" will receive personnel remuneration for his/her work. This is in addition to their normal salary. The amount for plant breeders varies widely but generally ranges at 10 to 50% of the royalties collected by the university. This can add up to hundred's of thousands of dollars. The inventor in the case of a breeding program need only insert a single gene into a plant. This is in addition to the 30,000 or so other genes that are already present, and needed to make a complete plant. By adding this one gene the "inventor" and company now own it. It seems absurd that the farmers and other researchers that over the past 10,000 years have improved that plant to the point that it was prior to gene insertion are left out of this financial equation. In a way though, the farmers are included. They now are told that they must buy seed every year because they cannot replant patented seed.

Since the passing of the Bayh-Dole Act (and the several amendments that followed) the Land Grant Universities have gone through a rapid transition away from the public service mission that they were founded on towards a true business model of short term vision and short term gain. Many plant breeding programs have gone right along with the universities in this transition. This is especially true in crops such as wheat where there are few private breeding companies. Today virtually all of the public breeding programs now have confidential agreements with biotech firms to collaborate on gene insertion with the goal of varietal development. Plant varieties that were once free to growers are now coming with "stewardship agreements" and other legal forms of control of the seed that prohibit farmers from planting back seed that they themselves have grown. Does it not seem fair to question the involvement of universities in taking away from farmers a right that they have had for 10,000 years, the right to save seed?

The most common arguments for commercializing public university breeding programs are:

1. Public private partnerships are required for progress.
2. We have to reward faculty in order to keep them. If we don't we will lose them to industry.
3. Patents are required to make scientific progress.
4. By helping industry we help everyone.
5. It's a funding issue; there are no other choices.
6. Without biotechnology (and all the ownership issues that come with it) we will starve!

Each of these points is discussed below.

Public-private partnerships are required for progress. The role of public research in the past was to serve the public. The role of private research is and always will be to make a profit. These two roles are exclusive. The argument however is often made that they are complimentary. Biotechnology firms in particular do not have their own breeding programs. In the case of wheat then the easiest way to market their genes is through the Land Grant breeding programs.

We have to reward faculty in order to keep them. If public servants need financial incentive in addition to their salaries to do their job then they should leave the university system.

Patents are required to make scientific progress. Patents are a negative right. They say what cannot be done in contrast to what can be done. The polio vaccine was developed without patents. What has changed in a few generations that require huge profits as an incentive for scientific discovery?

By helping industry we help everyone. If this were true we would not need laws to protect society from the excesses of industry. Industry has one goal and that is profit. This goal can contrast with common goals of society in such ways as the safety of workers and the environment. The public university mission is to serve society of which industry is a part. The mission should not be to blindly serve and subsidize industry. In addition the notion that public service can never compete with industry needs to be rejected. This way of thinking is a remnant from an early 1980's mentality that private industry can cure all that is wrong with America.

It's a funding issue; there are no other choices. This argument is heard often among geneticists. The problem is is that it is not true. The reality is that a scientist chooses their funding sources and industry money is usually easier to get than money with no strings attached. However, there are several scientists that have refused industry funding and are doing just fine with local, state and federal grants that do not require confidentiality agreements, have no restrictions on publication and do not include any profit incentives.

Without biotechnology (and all the ownership issues that come with it) we will starve! It is amazing that educated people at universities have bought into the idea that biotechnology will feed the world. Starvation has rarely or never been a matter of lack of production. It is a matter of poverty, politics and lack of infrastructure. The United Nations and other world organizations will tell you that there is about one and one half times the amount of calories on the earth today needed to feed all of the people alive. The problem is that the people in need are too poor and in such dire situations politically that they do not have access to the food needed to sustain themselves. How could biotech possibly fix this? It is a very callus advertising campaign that sells a proprietary technology based on the elimination of human misery. Biotech will not feed the world. Improved and more equitable economics and politics will. What about today? Can we reduce or eliminate the misery caused by the lack of food? We can, although it will be expensive and will take mundane approaches such as improving storage facilities and roads. The reason that people believe that biotech will feed the world may be because it is just too painful to accept the responsibility for the fact that we can end this misery and we have chosen not to.

The Dangers of privatization

Although by no means complete, the ideas above on why we have allowed the privatization of our public university breeding programs offer an introduction to the causes. Perhaps of more concern though is what the ramifications are. The main dangers of this type of rapid transition by our universities from a public model to a business model are duplication, direction, the loss of the disinterested voice and the loss of the idea of whom a public servant serves.

Simply if we let industry chose the direction of our research then we have duplicated not only industries goals but also those of other universities. Diversity of ideas will not only keep us vibrant but will also keep us needed. The public should have little interest in continually funding research that is being duplicated in other institutions and/or directed by short term profit motives.

Traditionally the university researcher was a disinterested voice. They could be trusted to evaluate fairly and not be afraid to give their opinion. If these same researchers now have confidentiality agreements related to their work and in fact might even profit from work performed at the university will they ever say anything bad about anything? It seems to be a fair question to ask.

And finally has the idea of what is science in the public interest changed over the years? It seems so and it seems to be tied back to the idea that public employees are not as good as their counter parts in industry. This of course is a ridiculous but commonly held thought. The shame is that public servants seem to have given in to this by not vigorously resisting the temptations to do their public science in a business mold. The result, and irony, may be the loss of public science altogether as society uses its own business approach of evaluation and weighs the benefits of maintaining these programs versus the cost.

Colorado Farmer's Comments on Public Food and Farm Research

Response to Keynote 3: What are the Key Issues in Ownership Concern and What is the Right Balance? By Steve Jones

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Much is wrong with public research institutions' collaboration with corporations in food and farm research. First, why do they want to risk their good reputation by associating closely with entities who, like BASF, has been fined hundreds of millions of dollars for price fixing as well as having a $53 million judgment ruled against it for defrauding farmers through abuse of the EPA herbicide labeling system? Or associate with Monsanto, who was found guilty of hiding PCB contamination for decades and who other biotech companies have sued several times, usually successfully, for stealing their intellectual property rights.

Furthermore, such association makes it hard to know where public researchers' loyalties lie. Over a year ago, I went to a promotional dinner meeting for Clearfield wheat. There, after BASF rep explained why farmers shouldn't save its patented Clearfield wheat seed, claiming they might be saving herbicide resistant weed seeds as well, he put a picture of Osama bin Laden in the projector in comparison of any farmer who would save seed. I immediately took issue, but most disturbing was the fact that neither the wheat grower association officials nor Colo. State University researchers present seemed upset about the comparison. In fact, one CSU researcher got up afterwards and spoke in defense of BASF's seed saving prohibition.

Consequently, when he spoke, I wondered whether it was he or whether it was BASF money that was talking. I am fully convinced that corporate contributions to the Wheat Growers Association affect its loyalty and judgment and am afraid to think they do the same to our public research institutions and researchers. I feel that the least BASF can do is let farmers save Clearfield wheat seed, since it put its herbicide resistance trait into one of CSU's varieties. And if BASF and CSU are so worried about resistant weeds popping up, rather than prohibit seed saving, they could require independent third party testing of saved seed. That is, if they can see past the next corporate contribution.

Everyone makes fun of President George Bush's misuse of the English language, but I wonder if Bob Dole, co-creator of the Bayh/Dole act, even understands English at all. By allowing public research institutions to patent, he allowed them to monopolize and to sell "exclusive rights" to the patents. But don't the words "exclusive" and "public" contradict each other?

And wouldn't public research institutions want maximum utilization of whatever research turns out to be beneficial? But under the monopolistic pricing schemes possible with products protected by patents, less of the product is sold and used than if the products were marketed under competitive conditions.

I keep hearing over and over that GMOs benefit farmers. But technology that makes something easier to grow or increases the yield really doesn't benefit us, once widely adopted. Tell any farmer that he is going to have a big crop, and he'll smile. But tell him all farmers are going to have a big crop and he'll frown. That's because we all know only too well that a big crop in the aggregate is, surprisingly, worth less than a small one. Economists attribute this effect to what they call "inelastic supply and demand fundamentals."

For example, a few years ago, some North Dakota State University economists did a study called "Modeling International Trade Impacts Of Genetically Modified Wheat Introductions." One of the things that it shows that if RR wheat increases farmers' yields ten percent, like Monsanto says, and if it is widely adopted, farmers around the whole world will become worse off. And for those using RR wheat, the increased production will cause wheat prices to drop even more than the amount of money farmers would save through easier and improved weed control.

This isn't the only study showing this kind of a result. In "Roundup Ready Soybeans and Welfare Effects in the Soybean Complex," Iowa State University researchers say, regarding Monsanto's claim that RR soybeans will yield 5% more, "The scenario of b0.05 (5% increase) generates large welfare losses for producers for almost every scenario … These massive welfare losses for the producers are due to the price decline that is associated with the supply shift due to the yield effect."

But don't misunderstand me. If we can grow more of something and do so in an environmentally friendly way, by all means, I think we should. However, we must do what we can to make sure the benefits of improved seed and other technologies are more evenly spread. That's not bound to happen if public research institutions are no longer able to come up with new varieties of seed that we can save freely, as opposed to having to be at the mercy of monopolists who can raise the price of seed as they see fit, even when that same seed is increasing the financial pressure for farmers to save seed. Also, we need seeds that come with no restrictions as to how we may market the crop grown from them. With patents, seed companies can ensure that farmers get aid as little as possible for their crops while ensuring consumers pay the most by controlling the marketing and processing of those crops.

So, how do we get the "public" back into "public research"? I understand state and federal governments are reluctant to adequately fund Land Grant Universities. I wish consumers would see the need to better fund public food and farm research, but it might take a train wreck regarding GMO food or environmental safety, for them to see. But if it does happen, Heaven forbid, the opportunity to show consumers that food and farm research should be mostly in public rather than private hands must be seized.

How might farmers be willing to help fund Land Grant Universities?

For my part, I wouldn't mind giving up farm subsidies to go for increased public breeding. But I don't know if too many others would be.

Many of us are already paying into checkoffs, that is, when we sell our crops and livestock, a small assessment is taken to fund market promotion and research, some which goes for breeding. However, checkoffs are not very popular among farmers presently and are under attack in the courts, as opponents say they violate Freedom of Speech. For my part, it upsets me when checkoff money is used o create varieties that Biotech companies get access to and then, after they insert their patented traits into them, they prohibit us from saving seed. After we helped pay for them, I feel the very least they can do is to let us save seed.

I believe, though, more farmers would be willing to pay into checkoffs, and pay more than they now do, if certain conditions are met. First, there must be an opt-out clause, for those who wish not to participate. Second, checkoff associations must not have incestuous relationships, that is, the sharing of offices and staff, with commodity organizations. This is a major problem presently as those organizations take corporate money, which makes me feel as if my checkoff money is going to help the corporations. Third, there must be no seed saving prohibitions, even if Biotech companies do insert their patented traits.

Missouri state legislator Wes Shoemyer has another idea for funding. He has introduced legislation that would let farmers save patented seed through the "Genetically Engineered Seed Fund." After paying administrative costs, part of the money would go back to the patent holder and part back to the University of Missouri for research.

Wes says there is very strong support among farmers in is area for this. However, he is fighting some powerful forces, not the least of which is Farm Bureau. Its lobbyists actively oppose his legislation while, surprisingly, its own policy "opposes restrictions on retaining seed produced by a grower for planting on his farm." But what can one expect from an organization that takes the money that

Monsanto makes from prosecuting seed saving farmers?

The farm and commodity groups which take corporate money, such as Farm Bureau, American Soybean Association, National Association of Wheat Growers, National Corn Growers Association, etc., will not fight for farmers' rights or support reforming checkoffs or promote legislation such as Wes Shoemyer's. The problem is that they have a lot of political clout.

I am encouraged, though, by the organizations sponsoring this conference, as well as by the numerous family-farmer friendly organizations that are fighting for farmers' rights and to keep public research public. It is my hope that someday we will be able to overcome the influence of the corporate money-takers.

Ownership and Legal and Public Policy Frameworks for Reinvigorating A Federal Public Plant and Animal Breeding System

Response to Keynote 3: What are the Key Issues in Ownership Concern and What is the Right Balance? By Steve Jones

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I. Introduction

There is evidence of a decline in public investment in public plant breeding while private investment has grown significantly (Frey, 1996; Heisey et al., 2001; Huffman and Evenson, 1993). One measure of this decline is seen when comparing scientist years. In a 1994 survey Frey (1996) found that federally funded agricultural experiment stations lost 12.5 plant breeding scientist years while private industry gained a net of 160 scientist years.

Patent and ownership laws have changed to encourage greater diffusion of knowledge and public/private partnerships in research. Licensing, patents and royalty income are on the rise at top U.S. universities. According to a survey by the Association of University Technology Managers (AUTM, 1997), U.S. research universities earned over $446 million in royalties from inventions in fiscal year 1997, an increase of 33 percent from 1996. Since 1980 over 2,000 new companies have been launched based on new innovations that were first licensed through an academic institution (Council on Governmental Regulations, 1999).

The ownership issues surrounding plant and animal germplasm and the differences in public and private research motivations have many policy implications that are growing in number and intensity.

Allowing patents on bacteria and seeds and thereby opening the possibility of patenting of other life forms raises ethical and moral questions. It also raises questions related to increasing consolidation in agriculture and the ability for large corporations to own increasing amounts of plant and animal germplasm and the repercussions this may have on the ability for small and mid-sized seed and breeding companies to compete. By allowing research and inventions funded by public dollars to be patented and sold to private companies, the 1980 Bayh-Dole Act and related amendments have changed the way public research institutions like land grants do business. On the one hand research is moved into the private sector and knowledge is diffused. On the other hand, public institutions have missions to serve the public good and if incentives focus on patenting for profit, are we losing research that might address critical social, health or environmental issues of concern to the greater public. Are we losing a longer-term focus by underfunding long-term research projects? Are public researchers being discouraged to delve into research realms that do not offer more immediate payoffs to the sponsoring institution? We need a greater understanding of the impacts that patent and other ownership laws have on the direction plant and animal breeding research is taking, who is gaining and who is losing.

Moreover, through paving the way for patenting of publicly funded research, these laws and policies encourage research projects that are more immediate and lucrative, rather than those that do not have a financial payoff or are longer term. In deciding what the next steps in ownership laws should be, especially as they relate to the use of publicly funded research, a greater diversity of stakeholders must be involved in the decision-making process. This is particularly true if we are to regain public support for plant and animal breeding programs in the public domain.

Current public policy is created by people and can be changed by people. Advancing scientific knowledge for a successful transition to a more sustainable future in agriculture requires maintenance of a strong public research base. This support for a strong public research base is at risk due to a crisis in confidence that will only be reinforced if the focus of grassroots and other public policy activities focus on the negative. Rather, public campaigns must focus on what they are "for"; and they must lay out a vision for a reinvigorated public plant and animal breeding system. Ownership is a crucial piece in the discussion of what this new vision will look like.

In other words, focusing on the negative aspects around land grant research expenditures may harm our very efforts to redirect resources to neglected research areas in the public interest. This is important in that any campaign must show a vision for how to address the crisis in confidence rather than only to reinforce it.

As knowledge and products created by the public research sector are encouraged by science and research policy to be patented and sold for royalties to private firms, more research is needed to understand if there is a resulting decrease in incentives to maintain a public interest research agenda that includes public domain plant and animal breeding.

While further study is needed to understand the broad impacts of the Bayh-Dole Act and the resulting increase in royalty and licensing fee income on the types of research conducted at our public research institutions we cannot only study impacts. Currently we know that public universities are receiving a greater amount of their research dollars from self-financing through royalty and licensing fees. A majority of this income is related to biomedical and agricultural products created through plant and animal breeding research. What we can see is a decline in public funding for public plant/animal breeding which is the key concern of this meeting.

So, in focusing on this concern we must ask where will the dollars to investigate plant and animal breeding concerns not funded by the private sector come from.

We need a balanced research agenda developed democratically with key constituencies for a more sustainable future. It is a crucial time to bring public and private plant and animal breeders, farmers, ranchers, business and legal community representatives, policy makers and other stakeholders into dialogue to ensure we continue to have a strong national public plant and animal breeding system.

I. Policy Background

A. Overview of Current Patent Law and the Bayh-Dole Act and Implications for Public and Participatory Breeding

On December 10, 2001, the U.S. Supreme Court issued an opinion in *J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred International, Inc.*, a case that dealt with questions concerning the patenting of plants and seed (McEowen and Harl, 2002). The majority opinion of the Supreme Court held for the general assertion that all life forms are patentable under current U.S. law, which has far-reaching implications for family farmers and ranchers and public plant and animal breeders.

The logical extension of the judicial decision on patenting life forms, absent development of a stronger statute by Congress, is that, for example, all livestock with various genetic markers would be patentable. Potentially, if livestock patents become the norm, producers might be forced to pay some sort of fee for every offspring produced with the patented genes or to pay for the ability to have patented livestock produce offspring. In other words, a farmer could own a cow that could not be bred without paying the fees. If the fees were not paid the farmer would risk being sued for patent infringement. The ramifications for independent livestock production, and ownership and control over on-farm breeding improvements conducted by a farmer/rancher, in this scenario are enormous.

In *J.E.M. v. Pioneer* case the Supreme Court ruled that newly developed plant breeds are patentable under the general utility patent laws. The utility patent does not offer a farmer or researcher exemption to save seed as does the existing Plant Variety Protection Act (*see Appendix 1*).

Simply, this means that public researchers and farmers cannot save seed - either conventional or GMO - that is protected under a utility patent. They still can save seed that is protected by a Plant Variety Protection Act certificate, but this law is useless in the face of the Supreme Court decision.

The Court upheld that any life form can be patented – bacteria, seeds/plants both conventional and genetically modified. At this time there is no law that bars livestock germplasm from being patented and in fact there are several patents now on animals (mice and pigs) and livestock. In the past Congress has considered legislation to place a moratorium on allowing the Patent and Trademark Office (PTO) to issue patents on living organisms (Hatfield, 1995).

Additionally, the 1980 Bayh-Dole Act, changed the law and made it possible for public funded research to be patented and to be sold for commercial use thereby encouraging technology transfer, the diffusion of knowledge and creating a new source of revenue for public research institutions.

The Act outlines rules for ownership of federally funded inventions including patents and Cooperative Research and Development Agreements (CRADA's). The Commerce Department administers the Bayh-Dole Act while the House and Senate Judicial committees provide oversight. The Act includes rules for agreements on disclosure, assignment of inventions, title to inventions, foreign patents, government rights to and funding of the invention, reports on utilization of the invention, and march-in-rights or the right to take over an invention or research if an agreement is not being met. Two clauses within the law are of special interest; one, that the product must substantially be manufactured in the United States or a waiver must be granted otherwise. Secondly, preference is given to small business firms of fewer than 500 employees. However, a large company may be awarded the license to an invention if that same company also provided research support that led to the invention.

It is also interesting to note that the Act states that inventors are entitled to "a portion" of any revenue received from licensing the invention. Any remaining revenue, after expenses, must support scientific research and education. The Comptroller General is required by 35 US Code 202 (b) (3) to review the implementation of the Bayh-Dole Act at least once every 5 years. The Judiciary Committees of the House and Senate are to receive the findings of these reports.[1]

If a land grant, through publicly funded research, modifies a seed and patents it (under the general utility law) they can sell the technology taking it out of the public domain.

One concern this raises is that the Bayh-Dole Act, combined with the recent Supreme Court decision allowing patenting of life forms, will accelerate the commercialization of plant and animal germplasm. This accelerated commercialization could result in less public access to seeds, sperm, etc. for family farmers and ranchers as well as for publicly funded researchers.

There is evidence of acceleration in patenting. According to a national survey by the AUTM (1997) over 8,000 U.S. patents were granted for inventions researched and developed by academic institutions between 1993 and 1997.

[1] Reports can be obtained from the Government Printing Office www.access.gpo.gov (reports).

Plant and seed germplasm are affected by the Supreme Court decision and the potential for general utility patents to be placed on livestock germplasm is equally great. Some of the implications of the Supreme Court decision as suggested by lawyer and agricultural economist Roger McEowen (with Harl, 2002, pg.) of Kansas State University (think not only plants but animal germplasm as well):

- "Accelerates the amount of germplasm that is held privately rather than in the public domain as seed companies devote additional resources to patent any seed that is economically worth planting
- Public plant breeders will lose access to germplasm
- Public research being directed to a greater extent towards satisfying the desires of the firms that purchase the rights to the patents or otherwise exert pressure on Public research, and to a lesser extent towards the desires of farmers and consumers
- Could lead to more concentration with more and more germplasm in private hands
- Reduced competition and innovation in plant breeding;
- More concentration due to small seed companies being unable to find new breeding material, and
- Greater control by firms holding patents over crops grown from patented seed."

B. Weighing the Pros/Cons of Bayh-Dole Act

As future policy option development and implementation of the Bayh-Dole Act moves forward it is essential to consider a balanced approach looking at the positive and negative impacts of the Act on both the private and public sectors individually as they are unique in their motivations and missions.

Positive impacts real or perceived:

- More licensing and royalty income for public research institutions in an era of declining public investments in agricultural research
- Diffusion of knowledge/technology that might not otherwise have been utilized
- Increase in private firms access to publicly funded research resources
- Increased collaboration between the public and private sector
- Emphasis on promoting small business R&D.

Negative impacts real or perceived:

- Decline in public institutional administrative support for research conducted that does not lead to licensing/royalty income
- Decline in academic freedoms
- Decline in public access to taxpayer subsidized research results
- Decline in support for long-term research projects due to the lack of immediate financial gain.

Empirical evidence, cost and benefit analysis as well as research and surveys on both the negative and positive impacts of the Bayh-Dole Act are lacking. There is a need for more research into the impacts of the Bayh-Dole Act and the role it does or does not play in the concentration of agriculture, directions of research and who benefits from the research, the transfer and diffusion of knowledge and technology and the promotion of innovation.

C. Goals of Public vs. Private Research

It is well documented that our agricultural system is concentrating into fewer and fewer hands (Heffernan et al., 1997). Laws that would foster competition are not being enforced, thereby accelerating consolidation. A case in point is the hog industry where a few large firms own most of the processing capabilities and can manipulate prices by owning livestock themselves. These same firms also control much of the production through their relationships with contract farmers who assume most of the risk, yet have very little decision making power on their farms or over supply and price. If these anti-competitive trends are allowed to continue unchecked, a portion of the unique American theory of dispersed ownership of property will disappear as small and mid-sized family farms and ranches will be lost and only the industrial giants will be left controlling the production of livestock and potentially most of the animal genetic resources. The risks to the environment from these concentrated contract enterprises include water and air pollution from high concentrations of manure, and reduced access to genetic resources as they are moved out of public into private hands.

Federal and state tax and policy incentives contribute to agricultural consolidation. Vertical integration led by a handful of large firms, many who have gotten larger by merging, is subsuming all levels of the agricultural distribution chain including seeds, the inputs by which they are grown, the transportation and storage infrastructure, processing and marketing. Increasingly these same firms gain time limited monopolies, or patents, on research results discovered through their private donations and relationships with public research institutions such as USDA and the land grant colleges and universities. This research is leveraged by the contributions of private firms, but is still financed largely with public dollars (examples include the technology to terminate the ability of a seed to regerminate developed by USDA and private firms – dubbed the "terminator" technology by some).

Little is known about the impact on change in the research directions of faculty at public institutions when policy and other incentives are focused on development of products or knowledge that then can be patented by the public research institution and sold to private firms for royalties. More research in this area is needed.

With the recent Supreme Court decision allowing utility patents for plants and other living things, the ownership of plant and animal genetic material by private firms is made simpler. The increasing ownership of genetic material by private firms will accelerate the trend of consolidation and vertical integration and will take away the last vestibules of local decision-making and control from family farmers and ranchers who will no longer own the rights to the "offspring" of their crops and livestock. If ownership of plant and animal germplasm by a few firms increases, then public access by plant breeders is lessened. With the loss of germplasm in the public domain, the public's willingness to pay for germplasm conservation efforts related to maintaining plant and animal diversity is also at risk.

II. Problems and Barriers to Adequate Support For Public Mission Driven Plant and Animal Breeding

A. Imbalance in Public vs. Private Research Expenditures

The share of University Research and Development (R&D) funded by the public has declined while the share of private investment and "self-financing" is on the rise.

David Mowery citing one example states, "Private industry now accounts for roughly two-thirds of national R&D investment in the U.S (2001, p. 254)." Mowery also argues that this dependence on private funding will result in R&D investments more attached and sensitive to the overall business cycle and economy. Therefore it is likely that we will see somewhat of a divestiture in R&D by industry since the U.S. is experiencing a recession following an economic boom. Mowery also evidences the, "share of university-performed R&D supported by federal funds shrank from 54 percent to 48 percent during 1970-1999 (2001, p. 257)." He then shows industry-financed R&D grew slowly from 5.3 percent in 1990 to 6.3 percent in 1999. Self-financing of R&D by universities grew between 1970 and 1999 from 8.1 to 16.3 percent in 1999 (2001). This increase in self-financing may be linked to the increase in licensing income made possible by the passage in 1980 of the Bayh-Dole Act but Mowery calls for more research to determine the causes of this trend in increasing university research self-financing.

Mowery voices another possible concern in that, "[t]he growing pressures on less well-endowed universities to match the efforts of others in self-financing research may also contribute to increased demands from political actors and academic administrators for congressional earmarking of federal research grants (2001, p. 259).”

B. Unknown Correlations Between Ownership Laws and Agriculture Concentration

Within the U.S., little attention is focused on the connections between:

- The 1980 Bayh-Dole Act (that allows publicly funded research to be patented and sold for royalties to private firms)
- The Supreme Court ruling mentioned above that now allows general utility patents on plants and, by this precedent, other living things (making meaningless the Plant Variety Protection Act and the Plant Patent Act); and
- The acceleration of consolidation, monopolistic control, cartel-like price fixing practices and vertical integration in livestock production and markets.

There is potential that the Bayh-Dole Act, if not reformed, will become the “back door” by which a few industrial agriculture firms will lock up key animal and plant genetic resources. In confronting the public/private research issue, we can also open the discussion on what needs to be done to ensure that producers and public researchers maintain reasonable control and access to animal and plant germplasm.

C. Need for a More Focused and Effective Public Campaign

Highly complex, and at times arcane, public policy, legal and ethical issues surrounding ownership of intellectual property coupled with the fast-paced introduction of genetic engineering and other “high-technologies” have overwhelmed civic and governmental capacities. One result, the “no GMO” campaigns are understandable in that the public sentiment surrounding these technologies is mixed, as are the research results evaluating environmental and health risks, the impact of “high technology” on increasing concentration in agriculture, and farmer/rancher profit.

However, pushing for “no GMOs” may be more of a “red herring,” while the “big whales” – the public policy questions of environmental, social and economic justice, corporate accountability, research in the public interest, and democratization of our research system - are left smoldering in the halls of the Patent and Trade office, Congress and the Supreme Court. Legal and policy decisions about ownership have been made and must be reviewed, better understood, and alternative policy options developed before a more effective public campaign is launched.

In other words: What are we for, rather than what we are against, is now the question the movement for a reinvigorated public plant and animal breeding system should be asking. If the problem, in part, is an imbalanced research system, how do we change it?

D. Patent Proliferation And the Need for Reform

Lawyer, John Barton (2000), argues that there may be too many patents on minor inventions that put the focus on protecting the original innovator at the cost of research by follow-on innovators. He also argues for tighter controls on determining patent validity and the need to more thoroughly review patent applications, even possibly by third parties as in Europe.

Barton suggests three reforms:

1. Raise standards for patentability;
2. Decrease use of patents to bar research (defensive portfolios are the norm with large companies); and
3. Ease legal attack on invalid patents by more thoroughly reviewing patent applications at the start.

The issue of defensive patent portfolios is an interesting one in our discussion of ownership and concentration in agriculture. Large firms often have larger patent portfolios and thus can use their portfolios to gain royalties from competitors and may also use them to restrict their competitors’ access to certain technologies. So, by encouraging commercialization of publicly funded innovations are we unintentionally giving preference to larger companies who can afford large patent portfolios and thereby encouraging anti-competitive behavior? Interestingly, Barton suggests two possible avenues to free up access to patented inventions for research purposes. First, that a provision be developed for a royalty-free license to use any patented technology for non-commercial research purposes, unless the patent holder is making the technology available through sale of products. A second mechanism might be a reasonable royalty compulsory license to allow access to patented inventions for research purposes.

Ultimately, Barton calls for a broader discussion and economic analysis of these and other suggested patent reforms.

V. Toward Finding Public Policy Solutions

Policy makers and farmers and ranchers are just beginning to get their heads around these complex interrelated issues, but they need help from those in the public domain plant and animal breeding community to understand the true implications for public plant and animal breeding and conservation, sustainable agriculture, family farms and ranches, rural communities, and competition in the marketplace.

Unique collaborations will need to be built for this work to be successful. Partners and stakeholders from the public and private research sectors, business, farm/ranch, legal, government, non-profit, consumer, faith, and other key constituencies will be required. Policymakers and scientists will play a crucial role as will the public through various grassroots advocacy efforts.

Policy avenues need further discussion, research and refinement. But below are suggested policy options to explore and discuss.

Potential Policy Avenues for Reinvigorating Public Plant and Animal Breeding Research Programming:

- USDA Reforms and Congressional Roles – Legislative and Administrative Branches
- Design and implement a federal advisory board for public plant and animal breeding research to make recommendations to USDA (ARS and CSREES) and to Congress
- Redirecting resources within ARS and NRI staff and programs to include public plant and animal breeding research for sustainable small and midsize family farm and ranch systems as a priority. Assist these agencies in developing language for Requests for Applications on grants and in setting budget requests and research agendas
- Request that Congress hold public hearings on how to re-invigorate the public plant and animal breeding system and then put pressure on Congress to appropriate necessary funding to put a strong system in place, including funding for a federal advisory board if appropriate.
- Increase federal formula funds and competitive grant funds (NRI program area) expressly for the purpose of educating and training public plant and animal breeders. Legislation might possibly include incentives for publicly funded and trained plant breeders to remain in the public sector for 5 years through reduction of school loan debt.
- Increase funding for the National Plant Germplasm System and non-profit sector germplasm preservation and development system through USDA budget, including competitive grant programs.
- Increase funding for research into implications of utility patenting on public sector plant and animal breeding as well as the implications of the increase in private expenditures and university "self-financing" on the

pursuit of public domain plant and animal breeding.

Ownership Policy and Law Reform:

- Develop policy options that strengthen current patent law (in the case of plants, utility patents now override the Plant Variety Protection Act and the Plant Patent Act that formerly safeguarded the farmers' right to save seed and provided access to seed for public breeders) to ensure the right of farmers/ranchers to own their livestock and the subsequent offspring they may produce
- Develop policy options related to safeguarding access to plant and animal germplasm for public breeding and research purposes
- Increase the ability of small and medium private firms to compete in contracts and partnerships with public research universities and other public research institutions and work to decentralize patenting of plant and animal germplasm and avoid further consolidation by a few firms. Strengthening related language in the Bayh-Dole Act is one possible option
- Further investigate and encourage broader discussion of patent reforms including: 1) raising standards for patentability; 2) decreasing use of patents to bar research; and 3) easing legal attack on invalid patents by more thoroughly reviewing patent applications
- Seek funding for a cost-benefit analysis of the Bayh-Dole Act and current patent laws for impacts on public plant/animal breeding research and access to germplasm by the public
- Research and develop administrative and legislative options for 1) new partnership and contractual structures that encourage innovation and move the knowledge and products necessary to meet fundamental human needs into the public sector 2) policies and programs to encourage these relationships between public researchers, private firms and livestock producers in ways that enhance opportunities for small and medium-sized enterprises, including farmers and ranchers.

VI. Conclusions

The face of public plant and animal breeding is quickly changing and in order to reinvigorate public commitment to the discipline an effective campaign to change public policy we must develop a vision and act swiftly and strategically. Decline in public funding of plant breeding and a rise in private funding has left a hole in education of the next generation of breeders as well as a gap in minor crops and longer term and systems research.

Patent and ownership laws, while diffusing knowledge more broadly, are also raising concerns that a resulting imbalance in the research agendas has led to greater consolidation of germplasm in private hands and neglect within the research system of cropping and livestock breeding problems of concern to the greater public.

A multi-pronged public policy approach is needed to reinvigorate public sector plant and animal breeding. An effective campaign will include considerations of policy and legal patent and ownership frameworks by a diversity of stakeholders who require access to germplasm including farmers, ranchers and public plant and animal breeders.

An effective campaign to reinvigorate investment in public plant and animal breeding will require vision and leadership. Clear policy options that result in more balanced research expenditures and research focus, patent reforms, and better understanding of the positive and negative impacts of current patent law and the Bayh-Dole Act are needed. Through research of current ownership policies and legal structures possible course corrections might be identified and then discussed among a diversity of stakeholders.

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Appendix I

Plant Patent Legislation:

Plant Patent Act (PPA)– Enacted in 1930 to "create financial incentives for breeders and to encourage the development of new varieties of plants."[1] The PPA was enacted because at the time Congress felt that plants could not meet the statutes for patenting. It was the intent of Congress at that time that plants were to be considered as products of nature and not amenable to the "written description" requirements of patent law (35 U.S.C. § 101). The PPA provides for the patenting of asexually reproduced plants.

Plant Variety Protection Act (PVPA) – Enacted in 1970 to compensate for the development of "true-to-type" sexually reproduced plants. A true-to-type plant is self-pollinated and non-hybrid. Under the PVPA certificates of protection confer exclusive right of owner to "exclude others from selling the variety, or offering it for sale, or reproducing it, or importing it, or exporting it, or using it in producing (*as distinguished from developing*) a hybrid or different variety therefrom" (italics added).[1] The PVPA includes a farmer and researcher exemption that allows farmers to sell the seed produced to another farmer for growing purposes. *(Asgrow v. Winterboer)*

More Public Interest Research is Possible at Land-Grant Universities

Response to Keynote 3: What are the Key Issues in Ownership Concerns and What is the Right Balance? By Stephen Jones

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Understanding Land-Grant Universities

It is easy to feel that land-grant universities (LGUs) have stopped responding to citizens in the states in which they are located. As Jones points out, pressures to sign material transfer agreements or to participate in university licensing arrangements drive researchers on campuses across the United States into doing proprietary research and/or profit-driven research. For the average citizen, it is hard to imagine how these research trajectories translate into improved quality of life.

Jones provides an outline of how this state of affairs came to dominate in the academy, even within land-grant institutions. Understanding the predicament is the first step toward achieving something different. Active involvement with universities might be the second.

Colleges of Agriculture Don't Exist in a Vacuum

It is important to remember that LGUs exist as part of a system that spreads across all 50 states and encompasses the research arm of the US Department of Agriculture. To change one LGU, requires significant changes in other "peer" institutions – other LGUs in other parts of the countries.

As universities face budget shortfalls across the country, they are constantly comparing themselves with their peer institutions and touting their perceived advantages. How many LGUs are determined to be the best Land-Grant University in the United States? Is it part of their mission statement? Perhaps, but more likely a university is focused on being a Research I university or achieving some other coveted status among university hierarchies. Is being a Research I university – and thus achieving the scientific recognition among a majority of its faculty – compatible with being a quality LGU that focuses on the needs of the states' citizens?

Each state and its citizens must answer that question in order for the university to achieve its land-grant mission. However, there are related questions about the system of science itself – including how one can obtain tenure doing public interest research given the tremendous pressure to publish in prestigious journals or win highly competitive grants. The scientific goals of these journals or the granting agencies are not always public interest ones.

Who Shapes Research Priorities?

Universities are sensitive to challenges that research conducted under their umbrella is biased towards industry. Thus, it is imperative that we follow the funding trail, as Jones contends in his paper. However, most citizens will be amazed at how little percentage of university research dollars actually come from the private sector. Consequently, it is important to understand how large agrofood firms and the associations to which they belong help to shape the research priorities and funding streams on the federal level. As Leval indicates, more citizen input on shaping research agendas, and increased stakeholder oversight on research programs is essential.

Such views can find broad support. Last year, the National Academies of Science published a document called *Frontiers in Agricultural Research: Food, Health, Environment and Community.* While USDA's historic focus on productivity has been admirably achieved, new areas of concern should be prioritized according to the Academy, including evaluating the impact of globalization, reducing food safety risks, understanding nutrition and human health, promoting environmental stewardship and broadening and diversifying the base for rural development and quality of life. We must be diligent in reminding LGUs and the USDA of the need for funding streams and programs focused on supporting these types of research.

How Land-Grant Universities Can Work Well

Find and Support Already Existing Public Interest Programs in Land-Grant Universities

It is important to remember there are programs at every university that work well for improving our common good in food and agriculture. These programs need to be supported and expanded. We need to increase the amount of funds for such programs, or the number of FTEs (full-time equivalents) devoted to public interest research, either through federal or state initiatives. In effect we need to establish a standard for what is considered public interest research at land-grant universities.

In Missouri, a successful integrated research and extension program was centered at the Forage and Grasslands Research Center in Linneus, Missouri. This was one of eight experiment station sites operated by the College of Agriculture, Food and Natural Resources of the University of Missouri. Researchers based at the Center worked very closely with the Green Hills Farm Project, a group of 50 family farmers who were intent on improving their operations. Research undertaken at the Center met the needs of the diverse group of farmers involved in the organization because researchers participated in monthly farm walks organized by the group. This close connection between research, outreach and farmer innovation is a perfect example of how programs can be devoted to the public interest, particularly in ways that are place-based.

While by most accounts a successful collaboration between the academy and community, much of the on-going grass-based research has been discontinued at this site due to internal differences in vision for the Center. Such an ending points to the need for stakeholder groups to be actively involved in dialogue with university administration in support of programs they deem useful to farmers and their communities.

The End of Check-offs and Commodity Group Influence?

Mandatory check-off campaigns for most major commodities have certainly contributed to shaping research priorities at large LGUs. Check-off campaign funds are collected for research and promotion activities so it is only to be expected that commodity group management and leadership can significantly influence research projects by providing much-needed funds to researchers. Many of these funds are provided in a non-competitive manner by selecting favored researchers and research projects – a very logical approach given the overhead necessary to administer competitive grant programs.

Commodity group leaders and managers often serve on LGU stakeholder committees and are often graduates of those same LGUs. As long as the interests of farmers and rural communities are promoted, this is not a bad thing for public interest research. But can commodity groups promote the interests of farmers within that industry rather than the "industry" as a whole?

Conclusion

Finally, it is important to remember that LGUs are still accountable to citizens of their respective states through state funding mechanisms. Citizens across the country need to demand accountability from their LGUs while refusing to settle for statistics and platitudes about what is already happening.

Keynote 4

Responses

Keynote 4 - Plant Breeding: Research and Education Agenda

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Introduction

I want to start this paper by explaining my biases and my current position. This will be helpful in understanding my position and perspectives on research and education in public plant breeding. I am the director of the Raymond F. Baker Center for Plant Breeding and the Pioneer Distinguished Chair in Maize Breeding. Both the center and the chair have been funded with gifts from either a private company or an individual that worked for a private company.

As a maize breeder I work with a crop that has the largest private investment in breeding of all crops. Frey (1996) showed that 25% of all the breeders in the U.S. were corn breeders. Much of my funding comes from the private sector and I have done paid consulting with the private sector. It is important to note, for me at least, that my interaction with the private sector rarely if ever involves germplasm exchanges. Most of my interactions with the private sector involve statistics, breeding methodology, and basic quantitative genetic research.

My general policy has been not to incorporate private germplasm into my breeding program. We do, however, use private inbred lines as testers for evaluating our elite inbreds in hybrid combinations. We do this to demonstrate performance to private industry breeders. Although you must sign a contract to access our new germplasm, you are free to breed with the germplasm and farmers may use it on their farms as long as nothing gets sold.

My assignment for this paper was to explore what kind of research and education agenda we need in plant breeding and how we go about implementing the agenda. The fact that we have to ask this question implies that something is or may be wrong with the current research and education agenda in public plant breeding. Whether or not a problem exists is probably more of a function of where you are at in the system and your perception of your impact and success. If you are a plant breeder at a public institution or agency you will measure success by funding, publication output, and germplasm releases. If you are a producer you will measure plant breeding success primarily by the availability of new cultivars that fit you requirements and perhaps in amount of information that flows your way.

My biggest discomfort during my 23 years in the plant breeding business has been the inability of plant breeders to document their impact. If we cannot demonstrate and articulate to the public at large, and this includes other scientists in the public sector, the impact of plant breeding programs, then the discipline of plant breeding as described by Tracy (2003) will almost surely disappear. As I look at the nationwide loss of corn breeders since I joined the business as a graduate student in 1980, I can only conclude that the elimination of public corn breeding positions by administrators was due to a perceived or real lack of impact in the breeding program. The administrative rationale for this is not hard to imagine. A corn breeder at a public institution retires, the administrator sees many private sector corn breeders, producers purchase nearly 100% of their corn seed from the private sector, the administrator does not see any evidence of past, immediate, or future impact of the position, the constituent groups are passive and do not speak up for various reasons, and the position gets converted from a breeder to something that at least seems to have a higher profile, ability to attract funding, and more immediate impact.

Versions of this scenario have been repeated many times and in many crops independent of whether there is a commercial sector involved with the crop. Little has been done to objectively analyze why this trend is occurring, except to blame it on a lack of funding for public plant breeding. The lack of funding is almost always the reason given for the demise of public plant breeding and for the inability of plant breeders to do their job. The question that then comes to mind is "if we give base level support to public plant breeding programs will that improve the output and quality of our public plant breeding programs?" My immediate answer is funding alone would have little or no impact on the output or quality of our public plant breeding programs.

This paper will be divided into several sections with each section addressing a pertinent question pertaining to the research and education agenda in public plant breeding. The questions will be: What is plant (and animal) breeding? What are the research and education models currently used in public plant breeding? What is needed to be successful? What about education? Why are there fewer plant breeders today? What are the major research questions that need answers? What is the role of the commercial sector in public plant breeding?

What is plant (and animal) breeding?

Tracy (2003) has given an excellent overview of what plant breeding is and how it is conducted. Rather than reiterate what he has said I just want to make two points about plant breeding. My standard definition is that plant breeding is the art and science of plant improvement. The root of the word art is doing and the root of the work science is knowing. Together this implies that plant breeding is done by people who have actively studied or are researching the underlying biological mechanisms involved in plant improvement. The art and science of plant breeding brings together the application, educational, and research aspect of plant breeding.

The practice of plant breeding, however, has been primarily concerned with separating the environmental component of phenotype from the genetic component of phenotype. Much of the research done over the past 75 years has been devoted to the statistical and quantitative genetic aspects of understanding this fundamental relationship. This is usually referred to as understanding the inheritance of the traits that are of interest. Unless this relationship is understood and appreciated it is doubtful that much genetic progress can be made in crop improvement.

An example from our research program on grain quality illustrates what I mean. In conjunction with Dr. Paul Scott, USDA-ARS, we have embarked on a selection program to improve the lysine, methionine, and tryptophan content of corn using conventional breeding methodology. We want to avoid using single genes because of known "side-effects" of these genes and instead have chosen the approach that Tracy (2003) has so well described. The major limitation in applying this methodology has been absence of cheap and fast analytical techniques for measuring amino acid content. Dr. Scott has developed some cheap high throughput methods, but before we can develop a breeding program around this technology we need to assess the repeatability of the methodology. If the measurement errors of the analytical methods are greater than the genetic variability we will not be able to make genetic progress for amino acid content. Likewise, if there is no genetic variation for amino acid content in our germplasm we also cannot make progress from selection. Fortunately this kind of research can often be conducted simultaneously with the design and implementation of the breeding program.

What are the current research and education models used in plant breeding?

Plant breeding research for most major agronomic and some horticultural crops in the U.S. has been heavily influenced by the USDA-ARS. Most of the USDA-ARS plant improvement programs that I am aware of are located in conjunction with a land-grant institution. In many cases, USDA-ARS scientists are located and housed with state scientists. In other cases, ARS scientists are housed in federal buildings on state campuses. But there are exceptions to this rule and some federal scientists are in federal labs that are not associated with a land-grant institution.

Because the USDA-ARS is a research organization without an educational component, the association of ARS scientists with land-grant institutions has in most cases increased productivity above what would have been achieved with an equivalent number of scientists of either institution alone. ARS scientists have a 100% research appointment, are not required or even allowed to teach a course, but have the benefit of being affiliated with an educational institution and being associated with graduate students. State scientists have the benefit of teaching, conducting research, educating graduate students, and being associated with well funded scientists that are research oriented. The continuation and survival of this relationship is in the hands of state and federal administrators who often seem unaware of the synergistic effect these relationships have had.

This influence of this relationship on the corn improvement program at Iowa State University started in 1922 and has continued uninterrupted to the present day. The program has frequently been cited as a model for federal-state cooperation and has been responsible for the development of the breeding infrastructure that currently exists in the corn program.

I am convinced that this cooperative federal-state model survives because of the emphasis on research that comes with being associated with the USDA-ARS programs and education that comes from the state programs. Research drives the funding in this model because output from research is much easier to document than output from breeding programs. The USDA-ARS requires its scientists to not only conduct research and but to also publish the research. State programs are often much more lenient on publication requirements especially after tenure has been received. The breeding program is then conducted to support and feed the research program. In this model research funding is what pays for the breeding program. Cultivar and line development programs can be maintained as "spin-offs" of the overall research program.

The second major model is the state breeding program with no associated federal component. These programs are funded primarily by commodity boards and/or end users such as millers or processors. Wheat and soybean breeding programs are excellent examples of these kinds of programs and frequently have strong and successful cultivar development programs. Since funding comes from end users, the focus is on breeding new cultivars or conducting breeding related research to solve producer problems. These programs also have strong research programs driven by the money obtained for breeding. Funding for this model tends to be more variable because of the source.

The third model we see is state scientists working on important and widely grown crops that are not cash crops. Most of the forages fall into this category, as do the so called 'minor' crops. Because there is no strong commodity or industry support these programs are funded primarily through external grant support. Small breeding programs can be associated with programs funded in this way, but the rigors of running a grant preclude the development of strong breeding programs.

Other models exist of course and there are continuous gradations between the three models. Even within a crop we see large variation in the strength and funding levels of breeding programs. There is no single reason to which we can attribute this variation. We can however, outline the basic requirements for a program to be successful.

What is needed to be successful?

I have identified five areas that are needed in order for public sector breeding programs to be successful:

- Research
- Breeding Programs Designed To Feed In To Research Programs
- Continuity In The Breeding Program – Build On Past Results
- Accountability
- Documentation of Impact (Quantify)
- Connecting With Other Areas Of Science
- Synthesis

It is clear to me that a strong research program has been a key factor common to most of the successful plant breeding programs across all crops in the U.S. It is no longer possible at most public institutions for breeders to run cultivar development programs that are not associated with strong research programs. The USDA-ARS has always used this model and has well defined research performance requirements. Although this does not maintain quality research it does keep the focus on research.

Depending on the research interests of the breeder, the breeding program can be designed to both feed the research program and develop improved germplasm. Once the breeding program is developed it is important to maintain continuity. The lack of continuity in breeding programs is frequently the cause of their poor performance. Breeders need to set and define clear objectives and design their breeding programs to obtain those objectives.

The next two requirements accountability and documentation of impact go hand-in-hand. Breeding programs must be accountable for the financial, physical, and personnel resources that have been allocated to them. We must be transparent in the use of those resources and clearly articulate what we have accomplished and why it is important. Agriculturists in general have been very modest about their accomplishments and we need to change this.

Documentation of impact in research programs is generally easier that it is in breeding programs. Impact in research programs is usually measured by the quantity and quality of published peer-reviewed manuscripts, the frequency that your manuscripts get cited, and the adoption of your science. Documentation of impact can be more difficult in breeding programs and is crop dependent. In hybrid crops like corn, where pedigrees are kept secret it is very difficult to assess the usage of germplasm from various sources – particularly if the germplasm is publicly released. One of the most important uses of germplasm licensing in hybrid crops is to track and quantify germplasm usage. If private companies want to see public hybrid breeding programs survive they must assist in this documentation. This same problem can exist in some self-pollinated crops as well, particularly if there is a strong private breeding effort. The important point is that we need to develop effective methods to convince administrators and the public that we are having an impact. If we are not having an impact why do we need to exist?

Plant breeding needs to do a better job of connecting with other areas of science. I, for one, have frequently lamented the loss of funding for plant breeding to biotechnology in the 1980s. In reality I am not sure this ever happened. The important point to realize is that all biotechnology applications must be delivered through a plant breeder. Plant breeders therefore need to be part of the conversation and have a say in the type of applications that get developed. This does not mean, however, that we turn plant breeders into biotechnologists.

Plant breeding is a synthetic field which makes it very difficult for people to conceptually grasp. In this way it is very similar to the field of evolution. For example, evolutionary biologists have taken it upon themselves to write numerous popular articles and books about the subject in an attempt to explain evolutionary biology to the public. Plant breeders need to do the same. It is very difficult to get people excited about something they do not understand.

What about education?

So far I have said little about education, but it is implicit in everything I have discussed. Good plant breeding education programs can only exist in the presence of high quality research programs. It is important to remember that both the M.S. and Ph.D. degrees are research degrees. In order for students to be awarded one of these degrees they must conduct a research project. What this means is that we cannot justify the existence of a plant breeding program on the need to educate (or train as many like to say) plant breeding majors. If you did not have a functional research program but did have a strong plant breeding program and someone gave you money for a graduate student, it would be very difficult to get that student a degree.

We need to do a better job of preparing undergraduates for a career in plant breeding. Many students graduating with B.S. degrees in traditional agronomy and crop science majors are not adequately prepared to obtain an advanced degree in plant breeding. These students are usually deficient in the biological sciences, mathematical sciences, chemical sciences, programming, and writing. All of these skills are required to be effective in research.

Why are there fewer plant breeders today?

The most common reason given in answer to this question is funding. Funding may be the immediate and local cause but it is not the global cause. Research priorities shift and funding streams shift with them. The reasons for these shifts are numerous, but funding rarely shifts away from research that is perceived to be having an impact or is actually having an impact. I contend that at least part of the funding shift from plant breeding has to do with our failure to document impact. Another part has been due to a lack of outreach associated with this impact. We need to tell people about the good things we are doing for them, because it is unlikely they will discover this on their own.

There has also been a fundamental shift in the way land grant universities operate. State funding is becoming a smaller piece of the funding pie at land grants. Fig. 1 shows the funding sources for Iowa State University for five academic calendar years. It is clear that state appropriations are slowly going down while tuition and contract and grants are increasing in importance. Universities have also been given economic development charges from state legislatures, which serve only to complicate the land grant mission.

Although the USDA-ARS has enjoyed strong funding support from congress, ARS is housed within a policy organization and research is often susceptible to shifts in public policy. This is frequently a function of the fact that plant breeders as a group have had no effective lobbying voice.

What are the major research questions in plant breeding?

There are still many unanswered questions regarding plant improvement and I cannot itemize all of them. I would like to bring out a few of them particularly in the context of sustainable and organic agriculture. The questions below are ones that have come up as I have interacted with sustainable and organic farmers and scientists on the interface of corn breeding. Because breeding programs need continuity, efficiency, and good management to be effective answers to these questions are important to obtain.

Do we need to breed under low-input sustainable and/or organic conditions?

Certainly the sustainable agriculture and organic community thinks that we need to and that is understandable. Unfortunately there is little evidence to support the need. I argue that we need to develop good solid scientific evidence to answer the question.

How do we identify and prioritize the traits that we select for?

We need to set consistent and achievable breeding goals that matter. The more simultaneous traits that we add to our breeding goals the more time it will take to develop useful cultivars.

Can farmers make progress selecting their own varieties on their own farms?

This answer depends on how you define progress and what the expectations are. It is important for people to understand that modern cultivars have had a tremendous amount of effort put into their development.

How do we distribute seed of publicly developed cultivars?

This is a crop-to-crop problem, but is particularly acute in cross-pollinated crops such as corn and alfalfa. Even if I developed a superior corn hybrid, I have no mechanism for delivering that hybrid to farmers.

We need research on developing efficient screens for the traits we want to select for.

The success of a plant breeding program is directly related to how easy it is to measure a trait. We are good at yield because we have spent years developing efficient ways to measure yield

Where does the commercial sector fit into public plant breeding?

This is complicated question, particularly for those crops with a large commercial presence. There is no single answer to this question. It is important to note, however, that the failure of plant breeding programs in developing countries is most often related to the collapse of public and private seed companies. Plant breeding is utterly useless if the seed cannot be gotten to farmers - and this is the role that the private sector has fulfilled in the U.S.

There are all kinds of sub questions related to this one:

Do we need public plant breeding when there is a significant commercial presence?

Will public plant breeding programs be perceived as being in competition with commercial plant breeding programs?

Who are the benefactors of public plant breeding programs?

How do public plant breeders divide their time between research and plant breeding?

This is certainly a funding related question. As I mentioned earlier, if all of my money came from grants and contracts, I would have to spend nearly all of my time on research and managing those grants and contracts. A good balance is needed, but it will be driven by funding sources.

Who does plant breeding outreach?

Someone needs to be charged with telling the public about the output from plant breeding research programs. Plant breeders can do some of this, but it is very time consuming. There needs to be a reexamination of the role of extension in universities. Traditionally extension has not done much with breeding and genetics.

Summary

The research and education agenda in public plant breeding must include the following features:

- Public Development of Useful Traits
- Delivery in Useful Germplasm
- Freedom To Operate
- Equal Access By All

All four of these features must be present for there to be success. These are also the same four features that must be present for public sector biotechnology to be successful.

Acknowledgements

I have had the benefit of conversations with many good friends over the years that have helped to shape my opinions on plant breeding. I take full responsibility for the opinions expressed in this paper. At the risk of leaving someone out, I would like to thank: Dr. Charlie Sing; University of Michigan, Dr. Wes Jackson; The Land Institute, Drs. Charlie Brummer, Jean-Luc Jannink, and Michael Lee, Iowa State University; Drs. Bill Tracy and Jim Coors, University of Wisconsin; and Dr. Walter Goldstein, Michael Fields Agricultural Institute.

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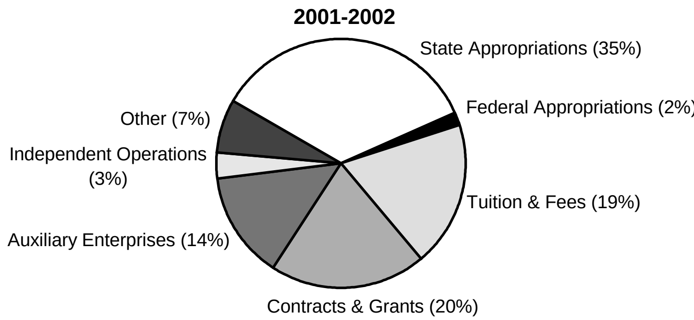
IOWA STATE UNIVERSITY

Revenues by Source (in thousands)

Fiscal Year



	–––1997-1998–––		–––1998-1999–––		–––1999-2000–––		–––2000-2001–––		–––2001-2002–––	
	DOLLARS	**%**	**DOLLARS**	**%**	**DOLLARS**	**%**	**DOLLARS**	**%**	**DOLLARS**	**%**
Revenues										
State Appropriations	$250,297	39.9%	262,550	39.8%	273,627	39.6%	281,459	38.6%	259,648	35.1%
Federal Appropriations	11,279	1.8%	11,899	1.8%	12,193	1.8%	10,802	1.5%	12,302	1.7%
Tuition and Fees	98,067	15.7%	102,696	15.6%	109,365	15.8%	118,332	16.2%	139,251	18.8%
Contracts and Grants	118,072	18.8%	124,346	18.9%	131,615	19.0%	139,990	19.2%	151,154	20.4%
Auxiliary Enterprises[1]	79,864	12.7%	85,659	13.0%	94,974	13.7%	103,649	14.2%	101,313	13.7%
Independent Operations[2]	25,902	4.1%	26,132	4.0%	26,332	3.8%	25,317	3.5%	24,433	3.3%
Other	43,076	6.9%	46,167	7.0%	42,989	6.2%	48,716	6.7%	52,371	7.1%
Total	**$626,557**		**$659,449**		**$691,095**		**$728,265**		**$740,472**	

[1] Auxiliary Enterprises: activities that exist to furnish goods and services to students and staff, essentially self-supporting, e.g., Iowa State Center, Residence System, University Bookstore.

[2] Independent Operations: operations that are independent of but may enhance the mission of the university: Ames Laboratory.

Office of Institutional Research (Source: Office of Controller)

Figure 1. The source of funding revenue by sources for Iowa State University. (http://www.iastate.edu/~inst_res_info/FB03files/finfac.html)

Public Plant Breeding:

Research and Education Agenda

Kendall R. Lamkey
Iowa State University

Plant Sciences Institute
Raymond F. Baker Center for Plant Breeding

My Biases

- My Position
  - Pioneer Distinguished Chair in Maize Breeding
  - Director of the Raymond F. Baker Center for Plant Breeding
- Funding
  - Grants
  - Private Funds
  - Consulted
  - Endowment Funds
- Germplasm & Private Sector
  - I Have Never used Private Germplasm in my Breeding Program
- Research & Private Sector
  - Most of my Interaction with Private Sector has been in Q. Genetic Research, Genetic Diversity, and Application of Molecular Technology

OUTLINE

- Is there anything wrong with our current research and education agenda?
- What is plant breeding?
- What are the framework/models currently in use for public plant breeding?
- What have been the success/failures of these models?

OUTLINE (Con't)

- Who determines what breeders select for?
- What are the major breeding questions that need answers?
- What are the major research questions that need answers?
- What is the role of the commercial sector in public plant breeding?

PLANT BREEDING

WHAT IS PLANT BREEDING?

The Art And Science Of Plant Improvement

Doing — Knowing — Value Judgment

PLANT BREEDING

- Plant breeders have either studied or are studying the underlying biological mechanisms
- Application, Education, and Research

PLANT BREEDING

Agronomy Department — Iowa State University

- Focused On Separating Environment From Genotype
- Trait Inheritance
- Necessary For Genetic Improvement

Public Plant Breeding 7

EXAMPLE

Agronomy Department — Iowa State University

- Amino Acid Content in Corn
- Current Analytical Techniques are Slow and Expensive
- New Methods Have Been Developed
- Repeatability and Reliability of Methods Needs to be Determined

Public Plant Breeding 8

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- USDA-ARS Labs
  - Adequate Federal Funds
  - Grant Money
- AES/State Scientists
  - Limited State Funds
  - Checkoff/Commodity Funds
  - Endowments
  - Grant Money

Public Plant Breeding 9

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- Cooperative USDA-ARS/State Programs
  - Adequate Federal Funds
  - Limited State Funds
  - Checkoff/Commodity Funds
  - Grant Money
- NGOs
  - Donor Funds
  - Grant Money

Public Plant Breeding 10

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- Successful Public Plant Breeding Progams Usually (Always) Have Strong Research Programs

Public Plant Breeding 11

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- USDA-ARS
  - Has Publication Requirement
  - No Educational (Teaching) Component
  - Limited Outreach Component
  - Limited Opportunity To Mentor Graduate Students (Unless Associated With A Land-grant)

Public Plant Breeding 12

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- **AES/State Scientists**
  - Have A Tenure Requirement (Publication – Get Funds)
  - Usually Have A Teaching Component
  - May Have An Outreach (Extension) Component
  - Mentor Graduate Students

September 8, 2003 — Public Plant Breeding — 13

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- **Cooperative USDA-ARS/State Programs**
  - Have Advantages that neither the federal or the state has alone

September 8, 2003 — Public Plant Breeding — 14

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

- **NGOs**
  - Are Free of Many of the Constraints on Public Institutions
  - Will Play a Invaluable Role in Education and Outreach

September 8, 2003 — Public Plant Breeding — 15

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

What Is Needed To Be Successful?

- Research
- Breeding Programs Designed To Feed In To Research Programs
- Continuity In The Breeding Program – Build On Past Results
- Accountability
- Documentation of Impact (Quantify)

September 8, 2003 — Public Plant Breeding — 16

ACKNOWLEDGEMENTS

Agronomy Department — Iowa State University

FEDERAL STAFF

- Dr. H. T. Jenkins (1922-1935)
- Dr. B. B. Bryant (1936-1939)
- Dr. G. F. Sprague (1939-1958)
- Dr. L. C. Penney (1949-1967)
- Dr. A. R. Hallauer (1958-1989)
- Dr. S. A. Eberhart (1960-1976)
- Dr. G. E. Scott (1962-1968)
- Dr. P. J. Loesch (1972-1980)
- Dr. O. S. Smith (1977-1983)
- Dr. L. M. Pollak (1982-present)
- Dr. K. R. Lamkey (1984-2002)
- Dr. A. Wright (1991-1994)
- Dr. M. P. Scott (1995-present)

STATE STAFF

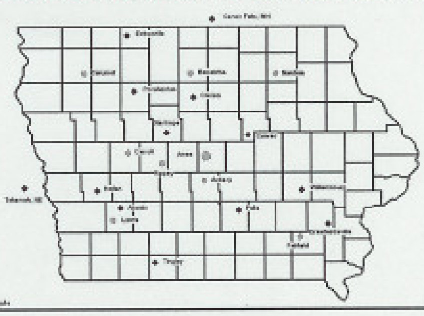
- Dr. W. A. Russell (1952-1989)
- Dr. Mock
- Dr. T. Crosbie (197?-1982)
- Dr. M. Lee (1985-Present)
- Dr. A. R. Hallauer (1990-2001)
- Dr. K. R. Lamkey (2002-present)

September 8, 2003 — Public Plant Breeding — 17

RESEARCH AND EDUCATION MODELS

Agronomy Department — Iowa State University

What Is Needed To Be Successful?



September — 18

What Is Needed To Be Successful?

- Breeders Need To Do A Better Job Of Connecting With Other Areas Of Science
  - Molecular Biology
  - Analytical Chemistry
  - Biochemistry
  - Chemical Engineering
  - Instrumentation
- Breeding Is Synthetic

What About Education?

- Education Should Flow Naturally From Quality Research Programs
- Do You Need a Ph.D. to be a Plant Breeder?
- The Ph.D. Is A Research Degree

What About Education?

- Better Prepare High School and Undergraduates for Careers in Plant Improvement
  - Emphasize math, science, chemistry, and programming
  - Establish Undergraduate Plant Breeding Curriculum

Successes and Failures

Why Are There Fewer Public Plant Breeders Today?

- The Most Common Answer I Hear Is Funding
- My Observation Is That Most Of The Plant Breeding Programs That Have Been Eliminated Lacked Strong Research Programs and Focus

Successes and Failures

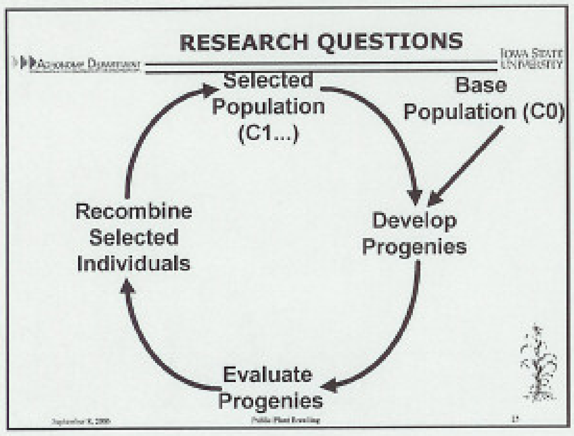
Why Are There Fewer Public Plant Breeders Today?

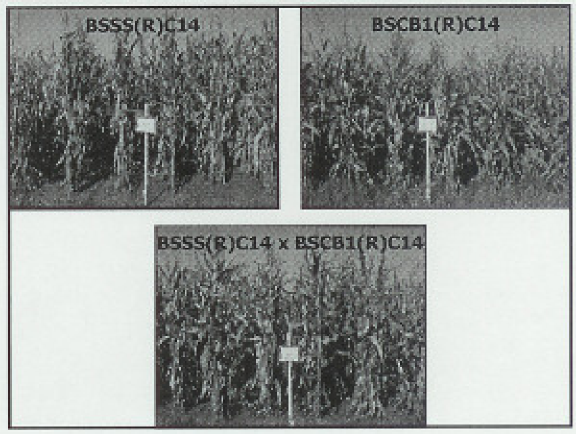
- Documentation of Impact
  - Who Uses the Germplasm
  - How Much are They Using
  - Has Research Made a Difference

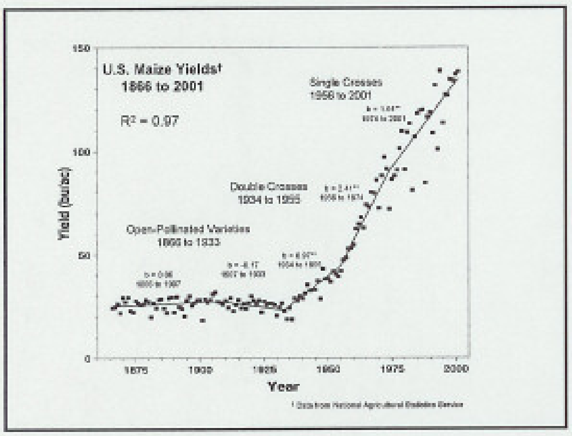
Successes and Failures

Why Are There Fewer Public Plant Breeders Today?

- Land Grant Mission vs. Public Support
  - Given Economic Development Mission
  - USDA is a Policy Organization







RESEARCH QUESTIONS

Agronomy Department — Iowa State University

Who Decides What Plant Breeders Select For?

- **Plant Breeders?**
- **Producers?**
- **Consumers?**
- **What Ever it is we Need to Know 10 Years Before you Need it.**

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

What Are The Major Questions In Plant Breeding That Needs Answers?

- **Commodity Crops**
- **Non-Cash Crops (Forage Legumes and Grasses)**
- **Alternative Crops**

Research Questions

Agronomy Department — Iowa State University

What Are The Major Questions In Plant Breeding That Needs Answers?

- **Participatory Plant Breeding**
- **Alternative Crops**
- **Systems Agriculture**
- **Wide Area vs Local Adaptation**

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

What Are The Major Research Questions That Needs Answers?

Interesting

Vs.

Important

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

Where Does Biotech Fit In?

- Input Traits (Herbicide & Insect Resistance)
- Output Traits (?? –Protein, AA, etc)
- Pharmaceuticals and Industrial Compounds

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

- Transgenes
  - One Of The Most Powerful Technologies At Our Disposal
  - Complicated
  - There Needs To Be Substantially More Public Research Done In This Area

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

- What Is Needed
  - Public Development of Useful Traits
  - Delivery in Useful Germplasm
  - Freedom To Operate
  - Equal Access By All
- Problems
  - Regulatory Hurdles
  - Intellectual Property Hurdles

RESEARCH QUESTIONS

Agronomy Department — Iowa State University

Where Does The Commercial Sector Fit In?

- Vary From Crop To Crop
- Relationship In Corn Is Healthy And Productive

Thanks

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- Jim Coors, Wisconsin

What Kind of Research and Education Agenda do We Need and How Can We Set it?

Response to Keynote 4 - Plant Breeding: Research and Education Agenda by Kendall Lamkey

Ron Rosmann

Organic farmer and President, Organic Farming Research Foundation, ronrosmann@fmctc.com

One of the beauties of being an organic farmer is that it has allowed me to begin thinking about integrated systems that enhance the health, productivity, and profitability of our farm. We have invested a considerable amount of time in deciding what crops to grow, what crop rotation sequences to have, how to lower purchased inputs, how to re-cycle nutrients through animal manures and composting and other practices that influence the entire farming operation. We have over 50 fields on our 620 acres certified organic farm. We raise over 16 different crops and livestock annually on this farm.

How do you educate people about the importance of public plant and animal breeding? First of all, you need to inspire them. You can do that by giving people some ownership in what they are doing. It gives all of us a feeling of belonging and that what we do makes a difference. All of us need to feel that we belong to a group or a community. Our rural communities continue to struggle for vitality. The county that I live in continues to slowly lose population. We need more farmers, not less, and we need farmers that can think on their own and not be relegated to a life of serfdom to the corporations that control so much of all of agriculture. There has been a great sense of inevitability and underlying despair that rarely comes to the surface in rural areas anymore. Where is the hope for carrying on the family farm tradition for the next generations? My wife Maria and I have three sons, ages 17,20, and 22. All three of them are interested in farming someday. All three of them like living in a rural area. We receive all of our income from our farming and organic meat business. There is no off-farm employment. "Seeds and Breeds" are the foundation of our farm and should be the foundation of all food and farming systems. Their importance on our farm cannot be emphasized enough. The role of the public sector in contributing to the improvement and vitality of seed and animal germplasm on all farms is at the very core of a sustainable agricultural economy.

What kind of research and education agenda do we need and how do we set it? The farmer-university researcher-plant breeder model is certainly where I would start. I, along with a number of other Iowa farmers, most notably Richard Thompson of Boone, Iowa started the "Practical Farmers of Iowa" in 1986. This groups initial and still primary focus is on farmers conducting credible on-farm research trials to gain answers to farming questions. What better way to get those answers than by teaming with the researcher and the plant breeder to frame the right questions and set the parameters for the research? I believe conducting research on working sustainable and certified organic farms is an absolute must if we are ever to increase our knowledge of farming systems. These farms need to have a "history" of sustainable farming practices in order to enhance the plant and animal breeding capabilities.

The idea of "farmer-breeder" clubs is a very intriguing one and if done correctly and followed through with over time could provide a great service to plant and animal breeding. I agree that it should be done in collaboration with the public breeding sector.

Do we need to breed under low-input sustainable conditions? I certainly think so. That is not to say that we should not breed for high input conditions as well. We have been doing quite well in that category. Low-input may not be the correct word. I would rather refer to it as something like regenerative inputs or cycling of nutrients on a crop and livestock farm to fully optimize the potential that exists for each field for instance. If certain critical inputs are lacking, then they have to be supplied from the outside. However, the first challenge is to try and create the on-farm systems balance that will keep these purchased inputs at a minimum. Crop rotations and crop and animal selections that enhance the sustainability of the farm are the goal. It is plant an animal breeding from a systems approach that will sustain healthy seeds and breeds. These would include yield and productivity, nutritional quality, disease and insect resistance, energy conservation, industrial needs for milling and processing, and ideally, desired social outcomes as well that would include rural and farm vitality.

If we need to breed under low-input sustainable conditions, what is different? A good example of this can be found in agricultural history involving the new technologies of hybrid seed corn, N fertilization, and cattle breeding. Ever since corn hybrids, Anhydrous Ammonia for N, pesticides, etc. all greatly improved corn yields after World War II, cattle have been selected more vigorously to be able to be fed greater amounts of corn and still not get too fat in the process. Cattle are ruminants and foragers by design and natural evolutionary succession. We have not fully optimized those basic characteristics. Perhaps we have been selecting for the wrong thing. Practically speaking, we should have been selecting for those species and those individuals within the species that perform well and grade well with less corn and more reliance on grass. There were other factors that led to more corn being fed as well. One was the surplus of corn that tended to accumulate after the advent of hybridization and improved soil fertility. It had to go somewhere. The deep-bodied English breeds tended to become too fat when fed large amounts of corn. This led to a backlash from the packing and food industry as well as the consumer and the health industry. We were finding out that too much fat was not good for you. The introduction of the "exotic" breeds of cattle that were leaner and taller, and in many cases bigger-boned led to longer feeding periods of corn to provide the choice, marbled beef that most consumers think they want.

Bt corn may provide another example. It could certainly be argued that Bt corn is an example of lowering inputs because of the need for less toxic insecticides. It does not however address some of the other questions involving the long-term lowering of inputs. This would include build up of resistance of European corn borers to Bt if sufficient refuges are not maintained, the possible destruction and decrease of beneficial insect species in the same field, the possible future lack of availability and effectiveness of Bt for organic farmers, and the question of diversity of varieties of corn, to name a few.

How do we identify and prioritize the traits that we select for? As an organic farmer, there is a great number of breeding needs that is not being met or even addressed. Each crop and breed of livestock has its own list of needs and concerns. Take soybeans for example. The tofu market requires certain traits that need to be present especially for the export market. (This in itself is an important point as commercial interests dictate to a large extent what they want from a certain plant or animal) This may or may not be sustainable however. The export market calls for a large, clear-hilum bean that is higher in protein. Taste and appearance are also very important. Walt Fehr, a soybean breeder at Iowa State University, developed a number of new public varieties that met these needs. Unfortunately, the last five-seven years have resulted in the widely spread problem of seed coat staining and discoloration from the soybean mottling viruses carried by the bean-leaf beetle. These particular varieties no longer perform well in our area. For much of the mid-west, the organic tofu industry has had to rely on older varieties some of which are public ones. Unfortunately, most do not yield as well or stand as well or have the size of bean desired. So there is very little soybean breeding going on to address this problem to my knowledge. The ability to perform well under organic growing conditions should be the number one priority for new seeds for organic farmers. This would involve such things as test weight, protein percentage, and other specific traits that the processors want and need. It would involve ability to compete with weeds and perform well under lower-nitrogen supplementation. It is definitely related to economics as well. I need to be able to market our organic crops and livestock for the highest premiums possible in order to maintain economic vitality. It our oats for instance are continually being rejected because of low test weight, or our soybeans are being rejected because of discoloration, or our wheat does not have enough protein, than we are losing badly needed dollars. These outcomes may have nothing to do with our farming practices but have everything to do with the availability of desired varieties, lack of breeding effort on specific crops to address specific needs, etc. It means more than breeding for yield.

The Organic Farming Research Foundation provides a funding mechanism for funding research projects that further advance the widely spread adoption of organic farming practices. Many of our projects over the last ten years as well as a number of current projects, are looking at seeds and breeds that can enhance the health and productivity of organic farms. In the future, we hope to look at supporting larger organic plant and animal breeding efforts through the possible use of donor-directed funds. The working organic farms of this country provide a tremendous opportunity to do the systems plant and animal breeding applied research that is so badly needed. The public sector needs to be educated about this need and opportunity. Our Land-Grant institutions as well as other public institutions need to be informed and persuaded of the valuable role that plant and animal breeders and sustainable and organic farmers working together can play.

Plant and Animal Breeding: Research and Education Agenda

Response to Keynote 4: What Kind of Research and Education Agenda do We Need and How Can We Set It? By Kendall R. Lamkey

Donald E. Bixby

American Livestock Breeds Conservancy, Pittsboro, NC, dbixby@albc-usa.org

Even though Kendall is obviously a "plant kingdomist," I am glad to see Ron's more zoophilic response and will join in his minority view of animal responses using Kendall's points.

What is animal breeding? Not only cattle, but also sheep and now goats are being selected for grain consumption rather then grass/forage, the natural source of nutrition for ruminants. We need to get agriculture off the corn addiction. Forage was formerly important for range reared swine, turkeys and chickens, all of which are now selected for indoor confinement rearing with not a scrap of green offered. At the same time natural nutrients are being replaced with synthetics designed from our imperfect knowledge base of nutritional needs.

Do we need to breed under low-input sustainable conditions? Perhaps the question has been asked in various forms over the past 30 years or so for plants but not for animals. Who as asked if we should select against resistance to parasites and foot rot, the need for antibiotics, growth enhancers, intensive confinement buildings, and utilization of natural forages? Instead of asking these questions, the industry has been offered increasingly expensive and complex input products.

If we need to breed under low-input sustainable conditions what is different? Reduction of grain feeding reduces many inputs: energy, transportation, pesticides, fertilizers, Bt seed, Roundup Ready soybeans, etc. Sustainable management changes can also address the increasing public concerns about the animal and human welfare issues associated with industrial livestock production as well as the nutrient value and other health issues related to animal foods produced in conventional industrial practices.

How do we identify and prioritize the traits that we select fore? This is a difficult and complex question to answer, but the traits and priorities will be different for each species, breed, product, and market. Some examples of traits of biological health leap immediately to mind:

- Cattle – good foraging ability that includes good G.I. and locomotor systems, longevity, fertility, product nutritional characteristics and flavor;
- Sheep – parasite, foot rot, and general disease resistance, fleece characteristics, pasture lambing, meat quality;
- Goats – already low input but the focus should be on improving production characteristics, which is relatively easy, rather than trying to change the production breeds to high input systems;
- Swine – foraging, fertility, maternal characteristics, marbling, elimination of stress gene, product nutritional characteristics and flavor
- Turkeys – foraging, reproductive efficiency, immune system health, breaking antibiotic dependence, biological conformation, product nutritional characteristics and flavor
- **C**hickens – Selection against antibiotic dependence and excitability, skeletal soundness, foraging ability, product nutritional characteristics and flavor

Can farmers make progress selecting their own varieties on their own farms? Historically, farmers made great selection improvement. Biological and environmental adaptation result from generations of selection on the same farm, or the same environment. All historic breeds are the result of farmer selection.

What is the merit of selecting for wide-area adaptation as is done commercially versus setting up regional plant breeding programs. Nature indulges a regional adaptation for good reason. Many traditional breeds of livestock retain adaptations as a result of generations of human and natural selection. These regional adaptations are complex and far more difficult to fix than "desirable traits." These adapted breeds also seem to be more adaptable.

Even if we set up public plant breeding programs how do we distribute seed? For livestock "seed" is distributed through breed association networks or even less structured connections. I don't know how public "seed" distribution might work, since everyone seems bent on patenting each new characteristic. This is an issue with which the Policy Coordination Committee of the USDA National Germplasm Program (on which I sit) is struggling.

We need research on developing efficient screens for the traits we want to select for. Once again this is at least species specific. This is often overlooked – but the reason we are so good at yield is because we know how to measure it. The traits needed for sustainability are not so much about output, but the margin between input and output. In addition to output we need to be selecting for biological fitness. Certainly fertility, reproductive efficiency, longevity of breeding stock, productive life. Dairy cattle are the great bad example of selective breeding. "Improvement" has led to fertility and productive life such that the national cow herd cannot now replace itself. Holstein cows on average produce slightly less than two calves, half of which are heifer calves, with a 10-15% pre-production mortality. What is the answer? Importing genes from New Zealand or France? Or maybe we just give up and import the milk from some other country since we have improved our cattle to the point they are no longer functional.

Where does the commercial sector fit in for those crops with a significant commercial presence? How does this question relate to animal breeding? If my understanding is correct, the commercial sector has no intercourse with farmer/breeders for swine or poultry, and relies on dairy and beef breeders only for the few bulls that enter the semen distribution market.

Kevin suggests that his biggest fear in the low-input sustainable discussion is that so much of what is reported is based on testimonials. " If we are going to develop a coherent plant (animal) breeding agenda it has got be research based. Let me give an example of what I mean. A farmer might say that they have been selecting in their OPV for several years and it now yields better or does something else better that where they started. This is a testimonial – a lot of things could be contributing to the increase. Only well designed experiments can show what really happened. I say this not to be critical of anyone, but if our institutions are going to take us seriously we need to have credible data."

Testimonials are, however, frequently the basis of good research questions. Since the farmers are providing the testimonials and the anecdotal information that suggest the questions that should be asked, public funding should be directed to capturing those data in a scientific manner in a collaboration between the scientist and the farmer, with the farmer being financially supported for his/her contribution. There is too much anecdotal information to ignore about closed herds/flocks increasing yield, health, and efficiencieies over several years/generations because of human selection and adaptation to the habitat. A similar effect has been scientifically documented in the transition from conventional to organic agriculture as the biome adapts to a different management system. This effect first came to the attention of scientists from a mass of anecdotal reports from farmers. These are the people in touch with the land. There are now so few of them that they cannot be ignored without great peril to our food systems.

What Kind of Research and Education Agenda do We Need and How Can We Set it?

Response to Keynote 4 – Plant Breeding: Research and Education Agenda by Kendall R. Lamkey

George Boody
Land Stewardship Project, White Bear Lake, MN, gboody@landstewardshipproject.org

Agendas for public plant and animal breeding need to be conceived within a larger vision of the public goods society needs, and overarching issues that make it difficult to fund this agenda. A number of examples of specific research topics are also mentioned.

1. The community needs to advance a larger vision of what is needed for the future that is based on an understanding of the ramifications of current agricultural practices.

   From my perspective, a vision should embrace interrelated crop and livestock farms that result in high levels of ecosystem services and other public goods, in a context of nested goals. These goals begin at a local level and include regional, national and global considerations. For example, in southeastern Minnesota, a Total Maximum Daily Load has been set for fecal coliform and may be set in the future for sediment and nutrients in surface waters. It is acknowledged by many that after an 80% increase in soybean acreage since 1987, the landscape in this area needs to be diversified. At a regional scale, exemplified by the driftless area of the Upper Mississippi River Basin, there are several native species conservation goals that relate to agriculture. A critical nested goal at the continental scale, is the reduction of large hypoxic zones in marine estuaries, such as the Gulf of Mexico. Last year the hypoxic zone in the Gulf was the largest ever at over 8,000 square miles. Research predicts that in-stream nitrate nitrogen reductions of 30 to 40 percent cannot be achieved in the Corn Belt only by using best management practices in the corn-soybean system.[i] A portion of the Corn Belt must be diversified into longer crop rotations, wetlands and perennial cover. The latter can be achieved, in part, by moving animals out of confined operations and into pasture-raised systems, as well as making bio-industrial products from perennial plants. In addition to policy and marketplace changes, this will require public plant and animal breeding within participatory, landscape oriented research programs.

An example of integrated research and plant breeding on a systems scale is the University of Minnesota's Landscape, Human and Animal Health Initiative. This group of 60 or so faculty, NGOs, farmers and others focuses on landscape quality and diversification. It includes research and enterprise development for perennial grasses and forbs, such as perennial flax, woody species, and wetlands. Human wellness and diet is another area of research along with animal well being and meat quality. Rural community development and urban/rural food system development are important components. Diversified production must be made economically feasible by developing suitable enterprises. This effort is closely linked with several Regional Sustainable Development Partnerships. These are University/Community partnerships that help define a research/outreach agenda for their area and direct financial resources under their control to begin the work. This type of structure involves citizens in identifying solutions and directing publicly funded research to meet those solutions.[ii]

A listing of more specific research (breeding) areas based on LSP's members' needs who are farmers, researchers, and food purchasers, include, but are not limited the following:

- Research and breeding on perennial plants suitable for diversified landscapes. We need to restore perennial crops to some portion of the landscape in the corn belt: perhaps 15 to 20% of the acres to begin with.
- Perennial flax could be fed to poultry and other animals to increase Omega3 fatty acids.
- Research and breeding is needed to fine tune and further develop innovative crop rotations that can be used for swine raised on pastures and in deep bedded systems.
- Breeding of plants and animals to function in pasture-raised systems for ruminant animals. This might include plants that can be set aside for late fall and winter feeding on pasture and warm season grasses for the August slump in cool season grass production. It is helpful to remember that humans are adapted to eat ruminant animals raised in pastures and that ruminant animals evolved to eat and digest grass.
- Crops that can be used in non-food uses such as whole plant oils, precursors to plastics and other industrial products. This can range from quack grass to a variety of other perennials
    - High levels of fertilizer application result in large nitrogen leaks into waters. We need breeding and agronomic research to develop corn and other row crops that achieve optimal, not maximal yields, using lower levels of nitrogen application that minimize negative environmental impacts.
    - Row crops and other plants that thrive in diverse and sometime multi-species cropping systems and have enough resistance to diseases and pests of various kinds to significantly reduce pesticides.

2. Overarching concerns and opportunities. To succeed in gaining visibility and increased funding for public plant and animal breeding, we will need to be well organized. The political and scientific climate tilts toward transgenic approaches that hold the allure of generating huge profits for multinational agribusiness firms. The Land Stewardship Project, Missouri Rural Crisis Center, and other partners demonstrated that well organized campaigns, such as helping pork farmers express their frustration with the mandatory checkoff and vote to end it, can mobilize the grassroots and lead to significant policy changes at the national level. This base of support, along with other organizing efforts, made it possible to encourage Senators to vote for a ban on packer ownership of livestock in the previous Senate. Policy change is possible if the people are behind it.

   We will need to figure out how to explain to farmers, the general public and policy makers how public plant and animal breeding is a fundamental issue of economic justice. This means we may also need to evaluate what kind of language we use. For example, the Minnesota Environmental Partnership conducted focus groups and polling about how the public understands various words and phrases. Stewardship was a word that resonated with people. The term “riparian” was not well understood, or worse, viewed as some sort of fringe political group.

   Participatory plant breeding, as outlined by Raoul Robinson, is a strategy that could also help to build support for and spur public plant breeding. The Land Stewardship Project and probably most in this room have used participatory research processes effectively in systems research work. This is one way of involving the public in setting the research agenda.

The public goods invested in varieties developed through publicly funded plant breeding need to be protected by being available to all, shared with other researchers, and uncontaminated by transgenic material. University policies about ownership of publicly owned genetic material need to be set or modified so as to support, not undermine the utility of current and future varieties. During the first day of this meeting it was suggested that:

- plant breeders paid by the public should not also receive private benefits through royalties and other financial arrangements; and
- all research funded with public dollars should be publicly available, and not bound by agreements with private companies demanding secrecy.

This is fruitful thinking. Public private partnerships with agribusiness can be useful. However, if large multinational companies demand too much, the response to them should be to say no. University faculty and administrators need to be held accountable for this and supported when they make courageous decisions that protect the public's investments.

Much has been said about the role that commodity support payments play in focusing production and therefore research on a few dominant crops. Single species commodity groups for the dominant crop and animal species more often promote systems and policies that have the effect of narrowing genetic variability and discriminate in favor of the largest farmers. Wider farmer participation in plant and animal breeding will be more easily encouraged as single species check-off programs become voluntary.

The Conservation Security Program (CSP) is something we should work to support and rally to get implemented. It can help bring about changes on the landscape. We could also learn from it and use it as a springboard to develop future farm policy that makes sense for family farmers, for the land and for healthful food. The original Senate language included "on_farm conservation and regeneration of biological resources, including plant and animal germplasm." That indicates a base of support that may still be there.

Finally, research and public plant and animal breeding based on a vision for the future that protects public goods and benefits will, by definition, require public funding. The current anti- tax mood in America complicates our work. Research that is not product oriented is a vitally important mechanism to protect society against risk from global climate change and other perturbations. Companies with products to sell may not choose to invest sufficient resources in these issues in a timely way. We will need to reach out to others facing this same dilemma and design campaigns to educate the public about the return on investment from these public dollars, and how making these investments could benefit their children and future generations.

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Keynote 5

Responses

Keynote 5 - What kind of Partnership Models Do We Need to Develop?

Walter Goldstein
Ron Doetch

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We would like to share with you a scenario of the kinds of changes and partnerships we think are necessary to develop in order to revitalize public breeding and to make a change in the food system. This scenario grows out of a vision of food production that involves linking environmental stewardship and consideration of great taste, nutritional value, and consumer health in all steps in production, including breeding, seed production, farm production and processing. To realize this vision on a broad scale would certainly necessitate a wide spectrum of changes and new partnerships on different levels. It would include changes in the thinking, roles and responsibilities of breeders, farmers, and seed companies, university administrators, processors, marketers, consumers and national policy makers. We believe that such a new paradigm, simple and naïve as it may sound, is the middle ground and the high ground many of us are seeking. Pioneering it could help to revitalize public breeding and re-establish the eroding trust between breeders and consumers.

As background, it seems that the industrial model of food production has been built on an unspoken social contract between public breeders, farmers, processors, and consumers. If they are thought about at all, breeders are thought of as providing healthy, adapted, superior plants and animals that will eventually feed the consumer healthy food. This trust has reflected itself in both the flow of dollars and in respect for the profession of public breeding.

However, these trust relationships are becoming increasingly delicate, in many cases they are frayed or crumbling, and they need reinforcement or replacement in real ways. A break in this trust has been exacerbated by genetic engineering, a phenomenon for which the public and processor were not ready. This development should not be construed as exclusively negative, because it gives opportunities for the public breeding sector to support new relationships and entrepreneurial partnerships associated with products that in some way re-guarantee that basic relationship between food and health, now in a more conscious way.

Actually, the present crisis in the relevance of public breeding, which has brought us together, should not be seen out of context from the situation of our food system and our science. The cutting edge of new, laboratory-oriented genetic science and technology, coupled with unlimited imaginations of future promises and interesting basic research, has lured away dollars, interest, and students. The field-and phenotype oriented technology of breeding is perceived as being old technology. We are a country awash in production, much of which has been the fruit of our breeding activities. If insufficient supplies of food due to low yields were a problem, our society would probably quickly ‘get real’ and invest more in practical breeding activities rather than investing so heavily in genomics.

Life’s challenges bring into question whether our societies’ philosophy of unending growth of production (bigger and more is better) is an appropriate or mature cultural goal or whether we as breeders should change direction and develop and champion new goals that encompass wiser use of our resources; goals that value qualitative as well as quantitative criteria for success. Everyone has an interest in eating enough of the best quality food. Breeders could form teams that would guarantee and educate about that.

Such a change of paradigm may or may not come, but if it does come it will certainly not come without transformation and struggle.

New Partnerships between Breeders/Farmers/Consumers:
Capturing the public's interest in health and taste within a breeding program is a potentially important avenue for development. For the breeder and farmer, yield has often been the bottom line while for the consumer, taste and health are often the bottom line. Something has often been left out in the industrial model of breeding; what has been neglected affects the end user. In the past the loyalty of the breeder has been with industry or with farmers, now we need to consider developing a relationship with the public.

Two important phenomena for us to consider at this conference are the interest in some consumer circles in high quality food products associated with older varieties or even primitive species (such as blue corn, spelt, kamut, amaranth, quinoa) and the growing move towards participatory plant breeding in developing countries. In the participatory breeding movement farmers are often the consumers of their products. Both of these 'movements' have a common thread: rejection of varieties produced by top-down breeding programs because they are viewed as producing products with poorer taste and quality. We should never forget that however high it yields, someone, whether human or animal, has to eat it; they will only eat so much of it, and it may or may not taste as good as it should. Nor should we reject out of hand the perception of degradation of quality that some consumers have of products produced by industrial oriented breeding programs. It seems often, though not always true, that the old-time varieties were more nutritionally dense or tastier.

The conundrum of public breeding is actually symptomatic of a prevalent quantitative-materialistic philosophy at our teaching institutions: we have been locked into a culturally determined bias in favor of ever increasing yields. Though breeding for yield has benefits, in the search for ever increasing yields valuable traits and quality may be lost. In fact, in many cases application of this one-sided philosophy has led to a decrease in quality of life, integrity, and health for animals and a decrease in taste and nutritional value of plant products.

A spectrum of examples to be given granted sufficient time for: sheep, poultry, rice, corn and others.

We surveyed farmers who strove for sustainability using ecologically sound farming practices for what kind of corn they wanted to have developed. We found they had a strong interest in nutritional quality and taste. Many of them are convinced that it makes sense to feed high quality, nutrient-dense, and tasty feed to their animals in order to avoid problems with illness. In fact, in some cases, one of their primary weapons against disease was good quality feed. In many cases they were willing to accept some reduction in yield in order to obtain higher quality. We view this relationship between quality and health as a profound observation even though it does not yet constitute a true change in paradigm amongst the larger population of farmers.

A future challenge for public breeders is to develop new approaches and interdisciplinary teams in order to enhance quality (including taste and nutritional value) as well as yield. In many cases this will not be easy. It will demand both the formation of interdisciplinary teams and financial support and guidance from wisely structured funding programs.

More than that, it will demand changes in our thinking on several levels. Breeders may need to change the way that they think about what they should be doing. Actually, breeders have more responsibility for the species they are working with than most others. In some cases they would do well to take on a different, more appreciative partnership with their species (which are after all not mechanisms or production machines). Institutionally, there needs to be a change in thinking about what breeding is and does. This re-think should lead to a re conception and upgrade in respect for the profession; it should also lead to an increase in funding for developing phenotypic science and appropriate ways for understanding, working with and adapting species and organisms. At the moment, it is problematic that in our educational system, more attention is often given to genes than to the whole organisms to which they belong. Breeders are trained to think that they are breeding conceptualized traits rather than living organisms and aside from general facts about production practices, adaptation, and reproductive biology there is often little thought about the species and organism as a whole and its integrity. However, in real-life breeding, the adaptation and response of the whole organism is crucial to success.

Actually, the challenge, fun, and frustration in breeding lies just in the fact that these species actually always appear and we are forced to work with them as living responsive wholes rather than simply as assemblages of parts, genes, or traits. Perhaps the goal of future breeding programs might be to breed with an ever-growing understanding and respect of what the species are and can become out of themselves with our assistance, by enhancing a *balance* of yields, quality, and health. In our opinion, a strengthened, more phenomenological, and more appreciative way of observing, thinking, working, and teaching is needed for breeding science to further develop and evaluate performance patterns or behavior of whole organisms on different levels. This more holistic breeding approach should better utilize rather than exclude human qualitative experience and enhance rather than degrade the integrity, health, and complex gifts of our companion species.

Besides yield, health, quality, and taste need to be evaluated as valuable output characteristics of a breeding program. Making this happen will necessitate involve interdisciplinary partnerships and science. The approach and outcomes should be tied into marketing, possibly right down to the story that goes on the box or package of product. In this way public breeders and their teams could concretely re-affirm their partnership with consumers.

Furthermore, breeding for sustainable farming needs to involve evaluating and selecting offspring, breeding populations, or lines under sustainable farming conditions. This should and will include farmers and their input. Admittedly, at this time evidence of the importance of breeding under sustainable conditions is slender because little research has been done to clarify the issue. Some preliminary results from our cooperative SARE and MFAI corn trials suggest that breeding corn under organic conditions may enhance its performance on sustainable organic farms rather than on conventional farms. Such selection may also have resulted in corn with an enhanced ability to compete with weeds.

New kinds of breeding, food production, and processing partnerships need to arise. There are several components that need to be addressed in order to do this. Manufacturers, processors, and feeders need to be helped to identify the kind of quality they want and what they can sell. Farmers need to think out and articulate what kind of improved breeds and crops they want to raise and why and how they fit together in their farms. People and animals need to provide information on what varieties they like to eat. Breeders need to get input from both farmers and end-users and to use it.

Furthermore, farmers need to re-orient themselves to better understand what the end users want and how to supply those needs in a reliable way. Future partnerships may involve direct contracts involving groups of mid-sized farmers with similar stewardship oriented farming practices. For grain crops such as corn the new pricing and cost formulae for farmers may have to include cheaper seed costs, somewhat reduced yields but increased value for enhanced quality traits and for ecologically sound stewardship practices, and coordinated, reliable, and timed delivery to end users, feeders, and processors. Similar relationships are envisioned for animals and their products.

The new partnerships need to involve seed companies of variable sizes that aim to thrive by providing a service rather than by controlling farmers and seed.

NGO's, universities, and entrepreneurs may all play a role in fostering these processes and putting together cohesive programs that will make such relationships and financial formulae work.

We would like to present an example of a team effort to forge a new vision and partnerships with corn. Corn is the highest yielding crop in much of the Eastern half of the country. Number 2 corn is still going up in yield. The highest yielding inbreds are patented and increasingly engineered to the chagrin of many farmers and international and domestic consumers. Symptomatic of these developments is a progressive decline in the interest of foreign markets in buying our corn.

A strategy to bolster the value of corn may involve coupling both production and breeding to ensure both healthy production practice and enhanced nutritional value and taste. With an appropriation thanks to the leadership of Senators Herb Kohl and Tom Harkin and their staff we have started a joint program involving USDA/ARS and ISU, two NGO's (Practical Farmers of Iowa and Michael Fields Agricultural Institute), and sustainable farmers in Iowa and Wisconsin. The intent of this breeding program is to develop populations and breeding lines of corn, using classical breeding methods, that are well adapted to the needs of sustainable farmers and which have enhanced nutritional value and taste. They are being selected on farms where N is provided through the decay of organic matter and where competitive ability with weeds is a necessity. Farmers are beginning to partner with breeders to grow populations and are participating in adaptive selection at early stages of the breeding on their farms. The breeders in our project are working with a biochemist to identify and develop corn cultivars that have enhanced protein quality and higher levels of carotenoids, which are known to have antioxidants and vitamin effects. The output should be cultivars and hybrids with a range of niche marketing possibilities; better quality feed corn, and higher quality eggs and meat.

Simultaneously we are developing relationships that include egg producers, pet food manufacturers, and university researchers to accomplish feed trials and to do preference tests of our best lines with both animals and people.

Alongside this project, the NGO partners in this project foster an future interest in setting up the above mentioned associations of farmers to produce and store the best corn cultivars or hybrids that come from this project and to ensure its delivery to the feeders and manufacturers, thereby capturing that portion of the food value for the farmers.

As the project moves along we will also have to address the need to help consumers recognize and purchase those corn or animal products that have integrity, health, quality, and taste guaranteed from the breeding and production and processing practices all the way to the table.

Skeptics may argue that we are wasting our time because processors have geared their production to standard, number-two-grade corn and will accept no changes. However, we would argue that that conception is outdated. Though Dupont was apparently unable to accomplish its full vision of transforming American corn production with high-oil corn, they apparently stimulated processors to think about the kind of corn that would be best for them. Recently, to our knowledge, several processors, including ethanol producers, pet-food producers, and poultry feeders, have sought out breeding programs to find corn that best suits their needs.

Policy makers, administrators, NGO's and funding:

Long-range thinking by universities administrators and national policymakers that value the long-term public good should encompass the need for public institutions to pro-actively support the development of agricultural systems that are more environmentally sound, and resource and people-friendly than conventional agriculture. Conventionally bred animals and crops may or may not produce well and be healthy on farms that strive for sustainability; in any case they would probably produce even better if they were bred under such conditions. This means a re-prioritization of available funds to support breeding as part of the vision of a healthy, ecologically sound agriculture. For example, it makes sense that a substantial portion of a future oriented program such as the National Research Initiative might be devoted to competitive funding for such whole-organism, science-based, interdisciplinary breeding research and development programs with an orientation towards health and the need to encourage the use of ecologically sound farming practices.

The federal system of rewarding farmers with Loan Deficiency Payments based on high grain yields is a disincentive for the production of high quality corn, which initially will probably give lower yields. We need leadership from policy makers to envision, design, and legislate incentive programs that would promote and foster the production of quality animal and plant products and their marketing. We also need to find ways for NGO's to partner in such legislation, and to provide the grass roots support to help make it a reality.

Participatory Plant Breeding For Vegetable Seed Growers

Response to Keynote5: What kind of Partnership Models Do We Need to Develop? By Walter Goldstein and Ron Doetch

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I would like to further elaborate on some of the good points that Walter Goldstein has made concerning participatory plant breeding. I am going to talk about our educational work at the Abundant Life Seed Foundation/Organic Seed Alliance and the evolution in the partnerships that we're forming.

We work with minor seed crops, primarily for fresh market vegetables that are typically produced by diversified growers on farms ranging from 2 to 20 acres. Most of the farmers that use this seed are selling their vegetables through CSAs (Community Supported Agriculture programs), farmer's markets, and other local or regional outlets. Most of the farmers we work with, both the seed growers and the end-users of the seed are certified organic producers.

The Loss of Vegetable Varieties for Specialty Markets

There is currently a confluence of factors that is severally affecting the availability of seed for many of the vegetable varieties suitable for specialty markets. As was mentioned by Mary Hendrickson, there have been a huge number of mergers in the seed industry over the last 20 years. This trend, which has only been accelerated in the last five years, has resulted in a situation where over 75% of the commercial vegetable seed sold worldwide is produced by five of the largest trans-national production research seed companies.

So what usually happens when two or three production research seed companies merge? Soon after the merger a combined product list is compiled from each of the component businesses listing the seed varieties in the order of their sales. Any varieties that fall below a certain level of profitability are dropped even though they may have been very successful items for a smaller, more specialized distribution company. The largest vegetable seed company, Seminis, is a prime example. It has acquired many other companies in recent years, and has dropped nearly half its product list since 1999 (RAFI International 2000; Seminis 2003).

There are two classes of crop varieties that frequently get the axe in this way;

- Specialty varieties that can serve very important market niches in various regions. Many growers have developed specific high-end market niches around specific, quality traits like a unique color, flavor, or texture that may only be found in one or two specific crop varieties that may be produced by only one seed company.

- A class of varieties that we refer to as "workhorse" varieties because of their wide adaptation and solid performance record against various environmental stresses. Workhorses are usually standard varieties, both O.P.s (open-pollinated varieties) and hybrids that many organic growers have come to rely on for their productivity under organic cultural methods. In fact, many organic growers have developed their organic cultural techniques around the performance parameters of workhorse varieties.

The real dilemma of losing a particular variety from one of these market classes is that there may not be another variety to replace it, which can have serious economic ramifications in a grower's ability to produce a profitable crop for a specific market slot.

Another disturbing loss of diversity occurs within the breeding programs of the production research seed companies. When large seed companies merge many of the breeding programs in the acquired companies are often seen as redundant to the larger parent company. On close inspection this is often not the case, with differences in breeding objectives and target markets (both geographic and market type) between these programs. Nonetheless, with mergers breeding programs are often cut or dropped all together

It's also important to mention the National Organic Program's (NOP) standards for seed, which requires that certified organic growers use certified organic seed "when commercially available." Although there is relatively little organic vegetable seed currently being produced, several of the larger production seed companies have begun to produce certified organic seed, recognizing opportunity in this market. However, more than one of these seed companies has publicly stated that they will only produce organic seed of a small subset of their varieties. Hence, the breadth of varietal choices available for organic growers who abide by the new standards continues to be limited.

Training a New Class of Seed Growers

All of these factors are narrowing the choices of crop varieties available to specialty vegetable growers, especially certified organic growers. A number of independent regional seed companies that have historically primarily brokered seeds directly to farmers are becoming increasingly aware of this situation. Over the past several years these companies have begun to contract with independent organic seed growers and have purchased organic seed of these increasingly hard to find varieties wherever possible. The seed companies have had mixed success with procuring seed in this way. Although there are a number of good organic seed growers, much of the organic seed being grown has been of variable quality and usually of limited quantity. Overall there is a serious gap in the farmer knowledge base on techniques used in producing commercial quality seed. These independent growers need help on basic cultural methods to establish a seed crop as well as harvesting and cleaning the seed. They also need to learn some of the basic skills of selection and roguing of the crop, as the regional seed companies they are working with don't usually have agronomists overseeing the production or genetic purity of these crops.

Seed grower education

We have begun to develop an educational model for new seed growers to teach the mechanics of producing high quality seed, and the roguing procedures to maintain varietal integrity in seed crops.

We have also established a series of more advanced classes, training seed growers in the crop improvement skills necessary for participatory plant breeding. Specific areas covered include:

- Evaluation of crop germplasm through on-farm replicated trials, keeping a "baseline standard" of any crop varieties that are being selected.
- Performing progeny selection to increase "gain from selection" over basic mass selection techniques.

- Selecting for horizontal or durable resistance in the field.

Seed company education

We are also working with independent regional seed companies through the training of their agronomists in:

- Evaluation procedures for quality traits and disease resistance in commercial varieties.
- Methods of maintenance and upkeep of foundation and stock seed for all commercial seed lots
- To assist them in making connections with the best seed growers from our trainings.

This is where the demonstration for our public-private partnership comes into play. The private seed companies are essential for distribution of the seed to growers, their understanding of the seed needs of this diversified market for specialty crops, and for their ability to develop new markets for new crop varieties developed by independent plant breeders.

Collaborations in Participatory Plant Breeding

These educational forums are leading us into collaborations with plant breeders, pathologists, and extension personnel at Washington State University, Oregon State University, and University of Idaho in a series of regional demonstration projects. This will include plots for seed production, disease nurseries, and breeding for quality traits on grower's farms in seed production areas of these three states. Cooperating growers will be involved in and assist at all levels in choosing the crops, traits, and field design for evaluation plots.

The emerging sustainable agricultural system needs a healthy and diverse seed production system. Participatory breeding can help support the development of such a system. Through the training of basic breeding skills and research practices, seed farmers can play a crucial role in building participatory breeding programs.

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Farm Breeding Club-Seeds for the Future

Response to Keynote 5: What kind of Partnership Models Do We Need to Develop?
By Walter Goldstein and Ron Doetch

Theresa Podoll

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Problem:

Wheat varieties we were raising were losing their vigor and may be "running out" soon. New varieties not particularly suited to organic production systems.

Questions:

- Can we keep older varieties and thru selection and conditioning keep them going or were they going to "run out" at some point?
- Would we continuously be looking for new varieties?
- How to identify varietal traits and develop varieties suitable to organic production systems?

Vision: Develop wheat and oat varieties that are hardy, disease resistant, and durable-- able to maintain consistent quality and yields decade after decade.

Return to Resistance—by Rauol Robinson is a guide for us. Helping farmers to establish clubs to do selection and breeding and work for their area.
Focused primarily on disease resistance that is durable-- i.e.) ability to plant potato seed back decade after decade and not have to worry about loss of quality or failure of a crop due to disease.

The Farm Breeding Club identified 3 farmer cooperators, a couple of oat breeders, and 4 agronomists from the University of Minnesota and North Dakota State University willing to work on this project.

The group focused on two questions:

- What varieties work the best now on organic farms?
- What varieties have traits that have some potential to do some breeding work?

The long-term goal is to identify desirable germplasm and work to create a wheat and oat varieties that have:

1. Good yield potential
2. Durable long lasting disease resistance
3. Quality traits such as suitable milling, baking, nutrition, and eating qualities
4. Competitiveness, hardiness, and durability
5. Nutrient uptake efficiency-- a good root system
6. Ease of harvest-- i.e.) resistance to sprouting

What is cooperative research?

Farmers lack the necessary time to really do what is necessary in a breeding program. They also lack much of the technical expertise, data gathering skills, specialized machinery and infrastructure. However, the farmer brings the whole history of the soils, climate, crops, pressure from weeds, disease, and pests, in addition to his experience in organic production. The research relationship is an important one: combines the experience of the farmer with university people with specific expertise, skills, specialized machinery, and infrastructure. Biological science goes beyond just gathering data. It also requires observation. Scientists do observe but not from the same perspective as a farmer does. Combining the two together makes for a much more productive way to do research.

Care of seed

Care of the genetic resources that is our seed must in many hands instead of few. Seed has to be planted and experience each growing year. There have to enough stewards of the seed and germplasm to make sure it is taken care of. A seed bank should not be a vault. The seed bank should be the garden. Seed must be dispersed across many seed savers so that seed can experience every environmental season and evolve with the changes.

Control of germplasm

Part of the vision of the Farm Breeding Club is to maintain germplasm in the public realm. The consolidation of the seed industry and the threats to biodiversity posed by transgenic genetically modified varieties or are of major concern to participants.

In the spring of 2000, first year that we did organic variety trials on the farms of our cooperators, one of the organic farmers raised the question of genetic purity of the seedstocks we proposed to use. We knew that transgenic wheat was being field tested at the same NDSU Research Extension Center where the foundation seedstocks for one of the wheat varieties we were including in the variety trials was grown. When we posed the question to NDSU, they replied that they could not guarantee the genetic purity of those seedstocks. This sent shockwaves through the organic community. Not only did it raise questions for the producer as to what would happen to his farm's certification if he brought contaminated seedstocks onto his farm, but also it raised ownership questions. If foundation seedstocks were to be contaminated with private intellectual property, who then owns that seed?

The Farm Breeding Club raised these concerns at the Northern Plains Sustainable Agriculture Society's 2001 Annual Winter Conference. Our membership drafted a petition to our land grant institutions that transgenic varieties be isolated from sites where foundation seedstocks are grown, conditioned, or stored. Since that petition was circulated for signatures and submitted to the land grant institutions in North Dakota, South Dakota, Minnesota, and Montana, there have been three known contamination events in the foundation seedstocks for soybeans. In the June 2003 issue of the Non-GMO Source, numerous other incidents of transgenic contamination of foundations seedstocks were reported. This type of contamination is a real threat to the work of the Farm Breeding Club. Genetically modified organisms are strictly prohibited in organic production. Contaminated seed is unacceptable in organic production systems. Transgenic contamination puts the organic producer at risk for market rejection. Any tolerances for transgenic contamination in both organic and identity preserved markets are subject to the demands of the marketplace and are not within the control of the producer. Pure seed is not a luxury but a necessity.

In order to meet the necessity of genetically pure seedstocks, we must increase our vigilance. Our seedstocks hold the germplasm that contains our breeding potential and the future of our crops. We must establish a zero detectable tolerance level for transgenic contamination of our foundation seedstocks. We must take steps to protect foundation seedstocks for cross contamination with transgenic varieties. We must step up our testing protocols to ensure that any contamination events are detected before they are allowed to proliferate and then move into certified seed production. If contamination is detected, those seedstocks must be removed from the foundation seedstocks system, and regenerated through stored seedstocks. To ensure that adequate genetically pure seedstocks are available in storage, foundation seedstocks programs should increase the quantities held in cold storage.

The Farm Breeding Club model is designed to give producers an active role in developing the varieties that meet the needs of their farming systems. Part of that vision is to maintain vigorous seedstocks in the public domain. Transgenic contamination threatens that vision. Join with us in protecting our genetic heritage by endorsing a zero detectable tolerance level for transgenic contamination of our foundation seedstocks.

Summit Conclusions and Policy Recommendations to Reinvigorate Public Plant and Animal Breeding

We all need to strive toward a more balanced research agenda developed democratically with key constituencies for a more sustainable future. It is a crucial time to bring public and private plant and animal breeders, farmers, ranchers, consumers, business and legal community representatives, policy makers and other stakeholders into dialogue to ensure that we can continue to have a strong national public plant and animal breeding system for the 21st Century.

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Summit Conclusions and Policy Recommendations to Reinvigorate Public Plant and Animal Breeding

Key Policy Recommendations:

Capacity - The Congress and/or USDA should:

- Appropriate funds to at least double the U.S. and CGIAR long-term capacity for publicly held plant and animal breeding programs over the next 5 years to meet the needs of 21st Century Agriculture. Substantial increases in public breeding funding will be critical if USDA is to meet the complex needs of American farmers and international and specialty markets, to increase environmental and financial sustainability, and to help fulfill the U.S. commitment to world food security. Special focus should be placed on programs that build meaningful farmer/breeder collaboration and emphasize both horizontal and vertical breeding for sustainable systems.

- Increase capacity to breed improved cultivars and breeds of both minor and regionally adapted major crops and livestock breeds as keys to a more diversified and secure food system.

- Ensure that the newly created Conservation Security Program (CSP) provides incentives and conservation practice recognition to farmers for the on-farm practices of seed saving, preservation, selection and plant and animal breeding activities, which can contribute increased biodiversity, longer and more diverse cropping systems and can contribute to richer wildlife habitats.

- Ensure that dedicated funding streams are created and specifically stated in the RFA for public plant and animal breeding research in all National Research Initiatives (NRI) and other USDA research programs.

Increase farmer participation in public plant and animal breeding:

- USDA should establish incentive programs for farmers and farmer associations to participate in testing, selection, seed increase, and evaluation of plant varieties now housed in germplasm repositories.

- The National Genetic Resource Advisory Committee (NGRAC) should be reactivated and be re-composed of broad-based stakeholder representatives with demonstrated experience and/or expertise in genetic resource conversation. A central focus of this committee's work should be to facilitate a comprehensive external review of the US germplasm collection, and its preservation status and also to recommend strategies for re-invigorating US publicly held participatory plant and animal breeding initiatives to make greater use of those resources.

- Partnerships should be fostered between public breeding programs, farmers and small and medium sized seed and animal breeding companies to provide affordable and marketable germplasm, to effectively use publicly developed breeds, and to increase farmer choice.

The research and education agenda in public plant and animal breeding must include:

1. Public development of useful and/or divergent traits,
2. Delivery of useful germplasm and
3. Freedom to operate and equal access by all.

Education -

Educating the next generation of public plant and animal breeders is crucial to maintaining the functionality of these disciplines. Incentives and encouragement for the next generation of public breeders are essential to improve food security and to meet growing consumer demands.

Congress and USDA should:

- Increase public funding and other incentives for LGUs, (including1890s and other traditionally under-served institutions) and for NGOs in order to maintain viable training and research programs for undergraduate and graduate student in the basics of traditional plant and animal breeding. Such university and NGO public breeding training programs should include real fieldwork experiences, plus strong emphasis on biology, mathematics, chemistry, computer programming and communication skills. These programs should also be sensitive to the employment potential and needs of both the private and public sector job markets.

- Develop and support pilot Master of Science programs in applied plant and animal breeding consisting of two years of classwork and a one-year apprenticeship leading directly to employment in a public breeding program.

- Increase federal formula funds and competitive grants expressly for the purpose of educating and training public plant and animal breeders. New legislation should include incentives for publicly funded and trained plant and animal breeders to remain in the public sector for 5 years through reduction of school loan debts.

- Educate the public, university and government administrators and public policy makers about the value and benefits of publicly held plant and animal breeding and the overall need for and importance of public service within the US Land Grant system.

Germplasm availability-

Congress and USDA should:

- Increase financial and personnel support for the collection, preservation and evaluation of germplasm collections and should encourage increased public use of the rich sources of genetic diversity in the U.S. germplasm collections by establishing an incentive program for farmers, farmer associations, and NGO's to participate in testing, selection, increase, and evaluation of plant varieties and livestock breeds now housed in germplasm repositories and the accession of additional germplasm not yet included in these collections.

Research -

Public breeding programs should be designed to do both valuable research and to develop improved germplasm. Breeding programs must be accountable for the financial, physical, and personnel resources that have been allocated to them. They must be transparent in the use of those resources and clearly articulate what has been accomplished and why it is important.

They should also focus on breeding **systems** of interconnected plants and animals that are ecologically and economically sustainable and readily available to the public. Public plant and animal research should be harnessed to produce seeds and breeds that perform well in diversified landscapes, that optimize the productivity inherent in multi-species synergies, and that perform well in localized eco-systems within particular soil types, climates, crop and livestock mixtures, and landscape designs.

Congress and/or USDA should:

- Develop the National Research Initiative and other competitive grants programs to include significant funding for programs specifically devoted to plant and animal breeding focused on environmental stewardship and quality.

- Target the public sector development of new or improved major and minor crops and breeds in order to address the economic, biological, and ecological needs of U.S. agriculture and consumer interests. This should be done to ensure that U.S. agriculture can make new contributions in the areas of energy, health, and the environment. Plant and animal breeding research should be encouraged and supported to target the development of new varieties and breeds that will encourage environmental stewardship, respond better to local food systems and conditions, reflect sound agro-ecology and heighten product quality.

- Link existing competitive research grants and rural development funding to value-added agriculture, genetic preservation and participatory animal and plant breeding initiatives.

- Increase SARE funding to provide producer grants and to create a new national priority area for participatory plant and animal breeding for sustainable agricultural systems. This should result in incentives for farmers to become active breeders and to form farmer/breeder clubs or teams.

- Target breeding programs and research to meet the needs of organic and other low-input and sustainable production systems conditions and specialty markets. This research would involve such things as breeding for better quality and optimizing the potential that exists for efficient management of inputs or cycling of nutrients on a crop and livestock farms. It may also include other specific traits that the processors and consumers want and need. Increasing plant competitiveness with weeds and for cropping and livestock systems that perform well under lower-nitrogen supplementation are also needed.

- Support research into the impacts of US Agricultural policy on public breeding programs, on barriers to crop diversification and on increased utilization of agricultural genetic resources and its conservation. This analysis should also evaluate the impacts of US Ag policy on the net profits associated with various crop and animal production systems and barriers created by policy that diminish opportunities for small and medium-sized enterprises, including farmers and ranchers.

- Develop new funding structures that will promote the formation and maintenance of interdisciplinary research teams in order to enhance quality (including taste and nutritional value) as well as yield. This will demand both the formation of interdisciplinary teams and financial support and guidance from wisely structured, long-range funding programs.

- Develop strategies to restore agriculture's diversity, to reincorporate part of its wildness, to reintroduce tight, local nutrient recycling, and to tap into the strengths and productive capacities inherent in every ecological neighborhood.

- Restore agricultural competition, provide more farmer choices and build policies that will specifically reinvigorate publicly-held plant variety and animal breeding activities and restore farmers' rights to save seeds and protect their right to save breeding stock.

Re-evaluate the impact Bayh-Dole Act on public plant and animal breeding-

Congress should:

- Conduct public oversight hearings on the impacts of plant patenting, the Bayh-Dole Act, CRADA, the recent Supreme Court decision on plant patents, and seed industry concentration upon public plant and animal breeding. These hearings should include an examination of why human and financial resources for PPBPs have both declined and become more concentrated over the past 10-15 years.

- Conduct a cost-benefit analysis of the Bayh-Dole Act and current patent laws for impacts on public plant/animal breeding research and access to germplasm by the public.

- Investigate and encourage broader discussion of patent reforms including:

    1) Raising standards for patentability,
    2) Decreasing use of patents to bar research and
    3) Easing legal attacks on invalid patents by more thoroughly reviewing patent applications.

Broaden Public and stakeholder participation –

- Development of this agenda should involve sponsoring a series of workshops with stakeholders including plant breeders, ecologists, farmers, and citizens and evaluation of the impacts of Federal Policy on public breeding, which should include public review of the Bayh-Dole Act, the CRADA system and the PVPA. Special focus should be placed on reaching out to farmers and consumers to better understand their needs.

- Our goal must be to ensure that core technologies and genetic and/other public resources are held in the public domain, conserved and available for use, in order to encourage and make possible future research, development and deployment.

Recommendations for Plant and Animal Breeders

Public Plant and Animal Breeders Pledge

Public plant and animal breeders should pursue objectives that enhance the public interest by addressing social, environmental, and community concerns, rather than solely focusing on production issues. Public sector employees should not receive personal financial benefit, beyond their salary and fringe benefits, from work done as public employees.

Any royalties/fees should be returned to public plant breeding programs that originated the varieties.

All research conducted by the public sector should be available to the public without restriction, and all financial support and other remuneration provided public researchers should be treated as public information.

Statement of Zero Tolerance

Because breeder and foundation seed stocks compromise the very basis of our food and agricultural systems, efforts to limit the contamination of these stocks by other germplasm, whether transgenic or non-transgenic, should be developed and enforced. Increasing numbers of farmers, consumers and markets depend on identity-preserved agricultural products, whose viability and future growth can be damaged by such contamination.

Regardless of the type of production technologies and systems employed or the market systems addressed - foundation seed stock programs must maintain these seed stocks in a state true to their breeding to enhance the American farmer’s ability to meet the growing consumer demands of very diverse domestic and global markets.

A national and international standard of a zero detectable tolerance for the presence of transgenes should be established for all breeder and foundation seed stocks of non-genetically engineered cultivars, utilizing state of the art PCR technologies.

Appendix 1
Successful Public Plant Breeding Programs

Breeding Open-Pollinated Vegetable Varieties in Organic Systems: The Public Seed Initiative and Participatory Plant Breeding in North America

by Mark J. Henning and Molly M. Jahn

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Consolidation in the vegetable seed industry has resulted in a diminished capacity to serve diverse markets and in some cases removal of varieties from product lines. This has resulted in more under-served seed markets in North America and in the loss of key varieties, particularly open-pollinated varieties that have been bred for excellent general performance and wide adaptability. These varieties have been particularly important to growers engaged in low-input or organic production. In order to generate necessary revenues, large seed companies have shifted to focus primarily on "prima donna" hybrids for the most lucrative markets. While there are many vegetable varieties with good quality available from smaller seed companies, many of these varieties lack disease resistance and very little breeding has ever been done in and for organic systems. In response to this need to better serve under-served markets, the Public Seed Initiative (PSI, http://www.plbr.cornell.edu/psi/) was formed in the Dept. of Plant Breeding at Cornell University in collaboration with non-profits and other agencies supported by the USDA IFAFS program. Partners include plant breeders at other public institutions (USDA and universities), representatives from the national plant germplasm conservation system and non-profit groups (NOFA-NY, Oregon Tilth) with interests in organic agriculture and conservation of genetic diversity. The PSI seeks to make the benefits of public (federal and state) investments in plant breeding more available to all growers, including those in underserved regions and those farming with alternative methods. Towards this end, we have set up extensive trials of existing public vegetable varieties through networks of growers in the Northeast and Northwest U.S. Because there was no organic ground available on Cornell research farms, it was especially important to assess the performance of public varieties (hybrids and open-pollinated varieties) in organic systems. Both non-profit associations and Cooperative Extension provided critical elements of these networks.

In order to support breeding for organic systems once we had identified key needs, we applied for and received a grant from the Organic Farming Research Foundation (OFRF) to breed an open-pollinated cucumber mosaic virus (CMV) tolerant bell pepper that is well adapted for northeastern, midwest and northwestern climates. This virus has been ranked highly as a widespread problem by conventional growers in industrial agricultural systems such as the Central Valley in California as well as by organic growers across North America. Because of its wide host range, it tends to be especially destructive for growers with diverse cropping systems. In pepper, a valuable and popular vegetable for most growers, particularly CSAs (Community Supported Agriculture), CMV can be a severe constraint to pepper quality (it causes disfiguring fruit symptoms) and yield. Using traditional plant breeding methods on certified organic ground (or land in transition to organic), we have begun to breed CMV resistance (originally found in a tiny Mexican hot pepper) into the open pollinated bell pepper variety King of the North, a proven performer in organic systems. The base of this program had resulted from previous grants to us to work out the genetics of this trait and develop breeding lines for use in California.

Although this resistance is controlled by several genes, the fact that we already had tolerance transferred into a bell type means that this project should not take more than about 6 generations or 3 to 4 years. In addition, we will attempt to improve upon this already good variety by selecting for more earliness, good quality, and performance in organic systems. King of the North is already well adapted to northern and central conditions across the U.S, is a favorite in organic systems, and has been selected and provided by Turtle Tree Seeds, a biodynamic and organic seed company in upstate New York that sells certified organic seed, who is also a partner in this project. Elizabeth Henderson, an organic farmer in upstate NY, has cooperated on this breeding project. NOFA-NY made this important connection for us.

Since we committed to do breeding on organic ground and our organic research farm was not ready this year, we grew the segregating F_1 generation (King of the North x Cornell parents segregating for type and CMV resistance) at Elizabeth Henderson's organic farm. Elizabeth has made selections for earliness, fruit type, flavor, and plant habit. Her selections correspond very closely with our own selections at Cornell's student run organic (not certified) farm, where we planted a back up plot

We anticipate having farmers who have been involved through the PSI project do quality and yield trials in later generations. They will help to evaluate the breeding lines and can also select out their own favorite strains from our more variable populations.

The PSI project has taught us several important lessons that have proven valuable in giving our breeding program new direction:

1. We had to build trust and credibility with smaller seed companies and particularly with the organic agriculture community. A number of smaller regionally based companies were literally unknown to us, and we were unknown to them. Some examples are Fedco (Maine), Turtle Tree (New York), and High Mowing Seeds (Vermont). In discussions with these companies, we identified an additional bottleneck we have addressed in the PSI. These companies had difficulty locating growers with the expertise to produce small lots of high quality seed, and when they did, infrastructure was not available for seed processing. We have designed a mobile seed-processing unit that is housed in a trailer and transported throughout the Northeast. This unit has been extremely popular among growers interested in supplementing their income with contract seed production, and has served as a useful outreach focus and teaching tool at fairs and other public events.

2. We have become more sophisticated about breeding for organic/low input systems and have a more comprehensive understanding of the traits necessary for varieties suitable for this class of previously underserved growers. The cooperative trials have already resulted in licenses issued to several smaller companies for materials Cornell had finished and not in use because they weren't suited for the West Coast hybrid markets or were only suitable for use as hybrid parents.

3. This project necessitated a discussion with the organic community about germplasm ownership and management. All our germplasm goes out under formal material transfer agreements to prevent unilateral aggressive moves by recipients.

4. We have realized that there are even fewer public breeding programs than we initially guessed that are actively involved in generating breeding material that is potentially interesting for the industry.

Our hope is that we will be better able to provide improved varieties to all our constituents from our traditional clientele which are now components of large multinational conglomerates to smaller regionally oriented companies or companies that serve specialty markets. This project has also demonstrated the value of participatory plant breeding methods and grower-based selection as an extremely efficient and cost-effective way to obtain information necessary to commercialize varieties and has laid the groundwork for more breeding in and for organic systems.

Organic Seed Alliance
Participatory Plant Breeding - Education and Application

John Navazio and Matthew Dillon

Farmer Education

The Organic Seed Alliance is training seed growers in the basic skills necessary for on-farm participatory plant breeding. This includes both theoretical and practical knowledge of the basic biological and genetic factors that must be understood to successfully select and improve crop varieties. This is accomplished through a series of classes covering the basics of reproductive biology, population structure, selection theory and evaluation techniques. Farmers are taught using examples of successful field improvement projects with familiar crops.

Growers are taught how to compare crops slated for improvement with standards as a means of comparing “baseline” performance through cycles of selection. Seed crops are planted under less-than-ideal conditions in replicated trials and in selection nurseries. Selection methodology for phenotypic recurrent selection and recurrent selection using progeny performance are emphasized. Examples of resistant and susceptible check varieties are used in all disease selection nurseries. Crops are scored on a 1-9 scale by multiple evaluators. Growers are trained in harvest methods to insure a balanced seed sample for subsequent recurrent selection plots.

Application

Seed farmers and regional seed companies that have taken the workshops are encouraged to work with us and other plant breeders in developing varieties that meet their market needs. Breeding projects fall into two categories; 1) selection for maintenance and improvement of existing varieties and 2) selection within segregating material from crosses produced either by the breeder or the seed grower. We conduct field visits in order to assess and assist students in applying workshop theory and skills when engaging in such projects. Together growers and breeders determine crop types, environmental challenges to be applied, and choice of traits to be selected. Breeders assist in evaluation and selection at several appropriate times during the season. Quality evaluation of seed stock produced occurs in subsequent seasons.

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Successful Public Breeding Programs
Restoring Our Seed

Restoring Our Seed is a participatory extension program to train farmers in organic seed production and crop improvement. Farmers learn how to integrate seed production into ecological, whole farm systems, incorporate habitats to attract beneficial insects and pollinators, select and breed seed crops for local adaptability and disease resistance, and how to harvest and clean seeds.

A team of cooperative and lay extension, master organic seed growers, seed companies and plant breeders is conducting conferences, farmer field days and producing demonstration seed growing fields and training materials for seed growers in Maine, Massachusetts and Vermont over a period of three years, 2002-5.

An educational program provides curriculum and workshops to integrate seed production and breeding research into school garden programs, and is developing a seed production, breeding and sustainable seed systems module for college-level students in cooperation with Dr. Mark Hutton, Maine Cooperative Extension (mhutton@umext.maine.edu). The project has established a partnership project with a Palestinian seed company in Bethlehem, and with Genesisseeds.com, an Israeli organic seed company, to advance crop improvement of indigenous Mideast cultivars using the methods of Dr. Raoul Robinson, author of Return to Resistance (download on www.sharebooks.ca) for durable disease and pest resistance. The Public Seed Initiative (www.plbr.cornell.edu/psi) has provided us with invaluable expertise, germplasm and brought their mobile seed cleaning unit to far-flung corners of New England to help small-scale seed growers clean seed. Dr. John Navazio (seedmovement@earthlink.net) and Frank Morton have provided workshops on ecological crop improvement.

The goal of Restoring Our Seed is to foster regional networks for on-farm organic seed crop production and improvement. We invite partnership projects. Visit www.growseed.org for details of our upcoming seed conference November 15-16, 2003, and other project resources. Generously funded by NESARE.

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North Carolina Agriculture and Technical University
Pork Breeding Program

Dr. Charles Talbott

The pork industry, land grant universities and research stations have developed and promoted animal efficiency and productivity by optimizing the housing environment and identifying diets and breeds of hogs to suit confinement rearing. As a result, the method of raising hogs has changed dramatically over the last forty years, as well as the focus on *lean* conformation of the finished hog. As a consequence, there is some indication that the taste has been bred out of today's hog. In a gourmet publication, *The Art of Eating*, Ed Behr (1999) suggests that "the lean (corporate pork) meat is almost impossible to cook without making it dry and tough; the flavor is bland, so the texture stands out". Similar to the Certified Angus Beef program (a breed noted for intra-muscular fat) small farmers can promote a different "upscale" pork by using breeds that will focus on pork taste exclusively and feeding diets (possibly apart from corn and soybeans) to enhance flavor.

Based on research conducted at NC A&T SU, additional work is needed to understand the effects of alternative feedstuffs on pork flavor. Farmers who have orchards may be able to produce *"Porque de Seasons"* by using finishing hogs to glean fallen cherries in the spring, peaches in the summer, and apples or acorns in the fall. Iberian Hams command five times the price of hams produced from conventionally (European breeds bred for confinement) raised hogs, due to the unique flavor acquired when Iberian hogs glean the acorns from under the cork trees. Farmers with excess produce i.e. pumpkins, goat whey, garlic, rosemary, sage, etc., may be able to produce unique flavors in the pork which are also unique to their farm and local niche markets.

However, alternative diets to produce niche-market pork are unlikely to influence flavor without adequate levels of intramuscular fat (IMF). It is likely that the niche market farmer needs to examine genetic lines of Duroc or Berkshire boars that have not been selected for lean gain.

Tamworths are a rare breed and were considered for this experiment because they are noted for their foraging ability; they also have excellent maternal ability for application in extensive rearing systems (Porter, 1993). Durocs were selected for use as terminal cross sires and are recognized for high IMF levels which are considered important for producing "upscale pork" for the Japanese markets (Suzuki et al., 2003).

To meet the growing demand for a more flavorful pork product North Carolina Agricultural and Technical State University will help 10 North Carolina farmers per year for the next three years set up unique hog operations, which are designed to help them replace revenue lost from a declining tobacco market.

The North Carolina Golden LEAF Foundation is providing funding for the project.

Just a few years ago, many tobacco farmers also raised hogs. However, as profit margins declined, most gave up and concentrated on something more profitable, like tobacco. Now that tobacco growing isn’t as promising as it once was, farmers are looking for something that they can do to make enough money to continue farming. That’s where we the hog project came in.

The market these farmers can meet isn’t the same market where larger producers sell their product. Instead, the project will focus on providing a unique pork product for the Niman Ranch Pork Company, with the hope that higher profit margins will make hog farming an attractive option.

The Niman Ranch Pork Company, based in Iowa, produces pork for upscale restaurants and grocery stores across the nation. They acquire hogs from small-scale producers who adhere to a strict code of animal husbandry, and who feed their animals natural feeds and raise them on pastures or deeply bedded pens without the use of growth hormones or sub-therapeutic antibiotics. The pork is then marketed as a specialty.

During the project’s first year, Heifer Project International will provide each of the ten farmers participating in the project with two mature boars and 10 mature gilts raised according to Niman standards. The Golden LEAF Foundation will provide the farmers with “hoop” structures in which to raise the hogs or funding to convert an existing structure into one that can house the hogs according to Niman Ranch standards.

From the original herd, producers are expected to produce at least 200 hogs per year for the Niman Ranch Pork Company, as well as the equivalent number of animals (12 gilts and two boars) to “pass on” to subsequent farmers accepted into the program.

Farm advocacy groups, including the North Carolina Coalition of Farms and Rural Families, will help A&T identify potential project participants. Among the criteria considered will be a history of growing tobacco and raising hogs, farm income, and a willingness to participate in on-farm research and the training of future participants.

Once chosen, these farmers will also receive technical assistance from North Carolina A&T State University’s Cooperative Extension and Agricultural Research programs, to teach them how to raise hogs according to Niman’s standards.

Heifer Project International is a non-profit organization that provides livestock to projects targeting hunger, in an effort to help people establish herds to meet their nutritional needs with dairy and meat products.

For more information, please contact Dr. Charles Talbott, Department of Animal Sciences, North Carolina Agriculture and Technical University (336) 334-7672.

FCGP:
The Farmer Cooperative Genome Project

The Farmer's Cooperative Genome Project connects small seed producers with plant genetic resources and public breeders. A project of Oregon Tilth, the FCGP distributes seeds from USDA seed banks and public breeders to growers and plant enthusiasts in exchange for their observations on plant performance. Participants learn about plant characterization, plant breeding, seed regeneration and marketing. With support from the USDA, and administered by Oregon Tilth, the FCGP builds relations between gardeners, commercial growers, and plant germplasm resources to fuel agricultural innovation and maintain our nation's most vital resource base–the seed.

The FCGP assists growers in accessing and evaluating varieties available through the National Plant Germplasm System (the US seed banks) and public breeders at Oregon State University and Cornell. Participants receive seed and assistance in return for their experiences in both images and written evaluations. FCGP participants share their discoveries and innovations through a seed exchange, website, and publication.

In the past four years, over 400 FCGP participants have evaluated 1250 varieties in the USDA's National Plant Germplasm System (NPGS). 187 participants returned descriptive information on those varieties, revealing the abundance of treasures awaiting discovery in our nation's seed banks. From salad leaf broccoli to slow-bolting cilantro, many of these varieties are ready for release to innovative gardeners and commercial growers.

Successes forged new relations with public germplasm curators and with public breeders. In 2001 the FCGP teamed with the Cornell Vegetable Breeder's Institute, NOFA New York, and the Plant Genetic Resources Unit in Geneva to form the Public Seed Initiative (PSI). PSI is made possible by a grant from the USDA Initiative for Future Agricultural and Food Systems Plant Genome Project.

PSI brings gardeners and farmers together with public breeders to breed varieties for organic systems, engaging growers in the plant development process, and building regional seed production capacity.

Oregon Tilth is a member-based organization that offers organic certification services worldwide. Through chapter activities, classes and workshops, on-farm research and demonstration, publications and outreach, and organic certification services Oregon Tilth works toward sustainable agriculture.

The FCGP and the Public Seed Initiative

PSI is a collaborative effort to bring the innovations of public breeders directly to gardeners and farmers. FCGP participants grow varieties developed by breeders at Cornell, Oregon State University, and other public and private institutions, to take part in creating new vegetable varieties for organic growing conditions.

2002 marks the first season grow outs of Cornell varieties. Cucumbers, cantaloupes, and squash with powdery mildew resistance, and blight resistant tomatoes with outstanding flavor and production traits were among this year's highlights. Seed from these grow outs are available to FCGP participants for free, and new varieties will be offered for distribution in 2003.

In addition, the FCGP and Jim Myers, Dept. of Horticulture, Oregon State University (OSU), are now collaborating to breed a new, open-pollinated, organic broccoli variety for commercial use in the Pacific Northwest. The seed from selections made by FCGP participants will then be combined and redistributed. When the variety stabilizes, it will be released to the public.

Who can participate in the FCGP?
Participating in the FCGP is easy and free. Growers of all sizes can access plant germplasm (seeds) through the FCGP for plant evaluation, seed regeneration, and varietal development. In exchange for seed, participants are encouraged to photograph and describe the plant variety. Very little is known about many of the varieties available. Growing them is a process of discovery. By sharing their discoveries, FCGP participants help to secure those genetic resources in the public domain.

The FCGP offers every gardener the power to reverse the consolidation of genetic resources in the hands of few corporations, demonstrate to the world our intent to preserve these genetic treasures as common heritage for all, and develop varieties suitable for organic growing conditions. Members can participate at any of four levels:

1. Characterization- members grow seed from the NPGS or Cornell and return information such as narrative descriptions, photographs, or internationally standardized forms.

2. Regeneration- members produce seed to preserve a variety for sale or trade according to standards that will keep that variety pure.

3. Development- members create new varieties through the traditional techniques of intentional crossing and selection.

4. Marketing- members work with each other to cooperatively process and market seed they produce.

How does the cooperative work?
The nature of the cooperative is up to the direction of the membership. Currently, members access true seed from the NPGS, Cornell, OSU and other reputable sources, grow out, and describe the variety. FCGP members help to evaluate potential varieties, and in exchange gain access to breeder seed. The FCGP offers support to growers to familiarize them with seed resources, the age-old art of seed growing, and the business of cooperative development. Seed growers grow seed to seed according to FCGP guidelines and may offer their seed for sale or trade through the FCGP Annual Report.

Members are currently working to create regional seed packing facilities and develop a system for coordinating seed to seed grow outs and producing seed of certified quality. The regional packing facility would coordinate members, offer technical assistance, publish a catalog of varieties, and store, pack and deliver the seeds for sale.

An Executive Committee directs the activities of the project until a rotating Board of Directors is established and the cooperative is formalized.

Why should you participate?
Growing seed is perhaps the most rewarding of enterprises. From just one seed, hundreds, if not thousands of seeds are produced. To witness and participate in this wealth and abundance is awe-inspiring.

As we rely more on backyard gardeners and farmers to maintain our genetic heritage, it becomes increasingly important that we are careful and knowledgeable about seed preservation.

The vast numbers of plants needing our attention warrants a legion of dedicated growers. Exploring regional varieties and developing new crops, growers working together add a level of integrity to seed preservation efforts and create a model for international cooperation.

Seed packing remains one of the most accessible means of creating a value added product. Instead of watching in dismay as a pound of seed sold for $25 is put into thousands of packs worth $2 a piece, participate in the FCGP!

The FCGP*:*

- Returns farmers and gardeners to the age old practice of seed preservation

- Improves farmer understanding of the National Plant Germplasm System

- Fosters the development of farmer owned, low cost, value added enterprise

- Strengthens the collaboration between growers, non-profit organizations, and public institutions

- Encourages the public to trial and evaluate plant varieties and publish their discoveries

- Is an international model for farmer owned seed preservation efforts

- Introduces new and traditional varieties to the gardener, farmer, and consumer

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Breeding High-Quality Corn for Sustainable, Low-Input Farming Systems

Linda Pollak, Walter Goldstein, and Kendall Lamkey

Background

The Latin American Maize Project (LAMP) showed that genes for high productivity exist in many exotic corn germplasm accessions. In turn, it is known from GEM (Germplasm Enhancement of Maize project) that many of these genes, as well as those for quality, can be transferred and expressed in early breeding lines developed from the exotics crossed to elite Corn Belt lines. These genetic materials, improved Corn Belt populations and lines, and their crosses are excellent starting materials for a breeding project that is developing lines and varieties with the traits needed for reliable production under alternative farming systems. Farmers using these systems have not always been well-served by the conventional agricultural industry. Use of these varieties will also enhance the agricultural diversity of the corn crop.

Goal

Our long-term goal is to develop corn varieties for low-input systems that can be used for feed and specialty markets, and compare their development and performance under conventional and sustainable agricultural systems. We practice traditional plant breeding techniques in adapted and exotic introgressed breeding materials to develop productive varieties with improved grain and seed quality, thereby gaining knowledge and germplasm needed by breeders and producers. We hypothesize that crossing and recombining adapted and exotic corn will result in wide variability for traits that will improve quality, yield under low nitrogen fertilization, ability to compete with weeds, and environmental stability. We are using this approach cooperatively with farmers using sustainable farming systems to develop improved varieties with good grain quality. We develop, select, and utilize adapted and introgressed populations and characterize them for agronomic and other characteristics needed for efficient production under sustainable agricultural systems. Through selection and crossing we develop improved cultivars. We take advantage of information learned from comparing results in conventional and sustainable environments to modify breeding methods by using the best environment at a particular stage of selection. Our cooperative partnership among corn breeders at USDA-ARS, Iowa State University, and Michael Fields Agricultural Institute helps to achieve this objective. Along with Practical Farmers of Iowa members, we work cooperatively to develop a model for participatory plant breeding with farmers in a traditional/analytical breeding project. We also jointly explore and evaluate methods of information dissemination.

USDA-ARS and Iowa State University, Department of Agronomy, Ames, IA 50011; and Michael Fields Agricultural Institute, W 2493 County Road ES, East Troy, WI 53120. Corresponding authors are L.M. Pollak (lmpollak@iastate.edu), K.R. Lamkey (krlamkey@iastate.edu) and W. Goldstein (wgoldstein@michaelfieldsaginst.org).

Appendix 2
Agenda &Participant List

Summit on Seeds and Breeds for 21st Century Agriculture

September 6-8, 2003 Washington, DC
Phoenix Park Hotel

Saturday, September 6, 2003:

3:00-3:30 p.m. ....Welcome, Summit goals and ground-rules

3:30-5:30.............................. Participant introductions and meeting goals

5:30 - 5:45............................ Break

6:00-6:15............................. Opening Comments Michael Sligh, RAFI-USA

6:15-7:00………………………… Opening Keynote

Lessons for Public Breeding from Structural Changes in the Agricultural Marketplace Mary Hendrickson, University of Missouri

7:00 ……………………………………Informal social time and dinner on your own

Sunday, 7 September 2003:

8:00-8:30 ……………………………Welcome/goals for the day - Michael Sligh, RAFI-USA

8:30-9:00 ……………………………**What is plant breeding?**

A background primer on plant breeding methods, terminology, capabilities and limitations, to provide a common foundation for this summit discussion. .

Bill Tracy – University of Wisconsin

9:00-9:30 ……………………………**What is animal breeding?**

A background primer on animal breeding methods, terminology, capabilities and limitations, to provide a common foundation for summit discussions.

Don Bixby - American Livestock Breeds Conservancy

9:30-10:00…………………………Break

10:00-10:30 ………………………**Keynote 1: What would 21st Century breeding programs look like if they were geared toward a more sustainable agriculture-objectives, goals.**

We need a vision to respond to changes that are imposed on us from outside over the next 25 years. These may include improving our environmental impact, cutting down on petroleum-based inputs, breeding for farming systems, and quality and the public. Will the current seeds and breeds work in new systems? How do we add other species, and structural infrastructure to support them? Why might we need public plant and animal breeders?

Fred Kirschenmann – Leopold Center

10:30-11:00………………………Panel 1: Comments and Responses
Stan Cox, Mary-Howell Martens, Charlie Brummer

11:00-12:00 ………………………Participant Discussion 1

12:00-1:00 ……………………..……Lunch at the conference site-

***Luncheon Speaker* –Raoul Robinson**

Return to Resistance- Breeding Crops to Reduce Pesticide Dependence

1:00-1:30 …………………………..Keynote 2: **The Current State of Breeding- How did we get here?**

How did we get to the current situation? We will review breeding in its historical context, and explore how policy, consolidation, university reward structure, our values and the way we think (e.g., breed for what industry wants, etc.), affect the structure and outcome of breeding programs.

Don Duvick, Affiliate Professor of Plant Breeding, Iowa State University & Pioneer Hi-Bred International, Inc. (retired)

1:30-2:00 …………………………Panel 2 Paul Johnson, Duane Falk,

2:00-3:00……………………… Participant Discussion 2

3:00-3:30……………………… Break

3:30-4:00……………………… Keynote 3: **What are the key issues in ownership concerns and what is the right balance?**

In this session we will explore the impact of the Bayh-Dole Act and innovative ways to serve the public and maintain intellectual property rights.

Steve Jones, Washington State University

4:00-4:30 …………………………Panel 3 David Dechant, Kim Leval, Mary Hendrickson

4:30-5:30…………………………Participant Discussion 3

5:30-6:00…………………………Break

6:00-8:00……………………… Reception

8:00……………………………… Dinner on your own

<u>Monday, 8 September 2003:</u>

8:00-8:30………………………. Keynote 4: **What kind of research and education agenda do we need and how can we set it?**

In this session we will explore the kinds of research and best ways of setting these agendas including the needs to respond to environmental and consumer drivers.

Kendall Lamkey Iowa State University

8:30-9:00 Panel 4……………. Ron Rosmann, Don Bixby, Marti Mellon

9:00-10:00 …………………… Participant Discussion 4

10:00-10:30……………………. Break

10:30-11:00 …………………….**Keynote 5: What kind of partnerships/models do we need to develop?**

How could we redesign breeding programs to tie in with farmers (participatory programs), connect with consumers, connect with seed industry, etc? What are the new models? How can we accomplish cooperative problem solving?

Walter Goldstein, Michael Fields Agriculture Institute

11:00-11:40 …………………….Panel 5 Ben Miller, John Navazio, Theresa Podoll,

11:30-12:30…………………… Participant Discussion 5

12:30-1:30 ……………………...Lunch at conference site

1:30-3:30…………………………**Summary discussion, Conclusions and Next Steps**

1:30 – 2:00*………………………*Congressional perspective, Hill challenges and opportunities

2:00-2:30…………………………Farmer, Academic, and NGO Perspectives

What have you heard and where do we go from here*?*

2:30- 3:00…………………………Participant Discussion of next steps

3:00 – 3:30…………………………Concluding remarks

3:30 ………………………………….ADJOURN

Seeds and Breeds Summit
Washington DC September 6-8, 2003
Phoenix Plaza

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