CONDUCTING AND IMPLEMENTING RESEARCH IN PRODUCTION AGRICULTURE: A UNIVERSITY BENCH SCIENTISTS' VIEW

(By Marvin K. Harris, Professor of Entomology and Philip J. Hamman, Extension Urban Entomologist and Program Leader for Entomology, Texas A&M University, College Station, Texas)

REDEFINING THE MISSION AND REAFFIRMATION OF THE CLIENTELE

The land-grant university systems including the State Agricultural Experiment Stations, the Cooperative State Extension Services and Colleges of Agriculture have fostered a unique environment for conducting, implementing, and educating our citizens about research in production agriculture. The purpose of this paper is to provide a university bench scientists' view of this process and to discuss ways to improve the conduct and implementation of research in production agriculture.

The institutional framework described above has evolved for more than 100 years--from a time when most citizens were closely associated with agriculture to the present where barely one percent of the U.S. population actually produces food and fiber for the Nation. This dwindling population of producers rely on agricultural research to provide ways to feed and clothe an increasing population, but, from the very beginning, the principal beneficiaries of agricultural research have been the consumers of increasingly higher quality, more abundant, low cost food and fiber available throughout the year. The gradual disassociation of consumers from direct participation in production agriculture over the past century has created a communication gap between those involved in agriculture and the rest of society. Agricultural institutions have been increasingly successful in contributing to food and fiber production, processing, marketing and storage but have become increasingly isolated from the consumer/taxpayer.

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The mission of agricultural research and implementation originally emphasized increasingly the quantity and improving the storage of production in an economically efficient manner. This multifaceted mission has always been primarily focused on the agricultural producer because producers were and are the originators of food and fiber for the consumer. A century ago, farmers and their families also constituted a significant portion of the consumer group, and institutions responsible for production agriculture came to be viewed as working for farmers rather than working with farmers for consumers. This was a fine distinction a century ago but is of crucial significance today because farmers and associated agribusinesses now constitute only a tiny fraction of the consuming population.

Institutions, by their nature, are slow to change. Thus, research priorities established a century ago emphasizing yield, storage and low cost production remained in place until a decade after World War II when food quality and environmental and social issues began to emerge as technology revolutionized agriculture. The agrarian mentality still permeates our society and its institutions, but the images we retain bear little resemblance to the industrialized farmers of today that produce our food and fiber. This anachronistic image has provided a continuing measure of consumer support as urbanization of the population took place. Agricultural research and implementation proceeded virtually oblivious to these social upheavals and skewed perceptions, continuing to modernize the agricultural production process by adopting new technologies as quickly as they became available. Publication of *Silent Spring* came as a shock and the price of agricultural progress has become increasingly evident to everyone over the generation that has followed. Unanticipated technological complications continue to plague production agriculture and resolving these problems requires reinvolving the consumer in the process.

The new challenge of *producing a reliable supply of more high quality food and fiber at less cost with the least adverse impact on the environment* goes beyond the farm community. There are alternatives to how we conduct production agriculture. But these too have a price, and the informed consumer/taxpayer should play a role in establishing which alternatives should be pursued at what price and what contingencies are most attractive when complications occur.

THE RESEARCH PROCESS

The typical agricultural research scientist is an expert in a particular aspect of a discipline. The scientist knows a lot about soil morphology or insect physiology or fungal epidemiology or economics of small farms, for example, and even within that small area, further specialization is typically required to develop a sufficiently complete understanding to find new ways to make decisions and take actions that impact production agriculture. The agricultural research scientist is guided by general principles derived from his/her discipline, and pursues specific investigations that offer the most promise for satisfying some general objective established by his/her employer. "Cheaper more abundant high quality food and fiber, reliably produced at less cost while minimizing adverse effects on the environment" would be a typical general objective. The university bench scientist is further guided by a job description and title that identifies an area or commodity assignment where efforts are to be concentrated, i.e., "insect toxicology" or "small grains plant pathologist".

The researcher is usually free to concentrate on particular aspects of this general objective commensurate with his/her skills and resources, but funding availability typically determines which aspect receives the most attention. This funding can be provided by Federal, State, industry or private sponsors as part of a targeted effort in a particular area or it may be sources allocated after a competitive process based on submitted proposals. Either way, guidelines are typically established from the top and specific research objectives of the individual scientist must conform to the program to be eligible. Opportunities for individual university bench scientists to vigorously pursue promising research areas outside of existing guidelines to impact production agriculture are very limited. Resources are scarce to begin with and most of them will be earmarked for areas outside the specialty of the researcher in production agriculture.

During the past two decades in our experience, existing resources have been seriously eroded by inflation and new resources have been earmarked for long range high risk efforts to make seminal breakthroughs in the conduct of production agriculture by emphasizing novel areas of science previously unassociated with funding from agriculture. Chemical ecology and genetic engineering would be two examples of these efforts. The dramatic expansion of the research process to many new areas and the erosion of resources in established programs has resulted in exacerbating already serious deficiencies in the development and flow of information and technology from the idea stage to application in production agriculture.

Our criticism is not in the direction resources have taken but in the degree to which they have been allocated to various facets of the agricultural production process. Progress in production agriculture has historically been made in small incremental steps and the few new resources for conventional work tend to be reactions to severe problems that develop rather than the implementation of a proactive well balanced strategy for production agriculture. The front line production agriculture research scientist today has very limited resources and is confronted with new problems on a regular basis. They are backed by a cadre of scientists increasingly removed from agricultural expertise and commitment who derive their rewards from grantsmanship, refereed journal publication and research findings that promise to impact agriculture in a decade or longer in the future.

Some agricultural institutions have gone so far as to adopt the view that research should be concentrated only in areas promising seminal breakthroughs with a decade plus time frame. This may result in excellent science but threatens to destroy the linkage between a research commitment to improving production agriculture today versus tomorrow. This is problematic because the farmer and, more importantly, the human valued resources they produce, must survive today to get to tomorrow. The luxury of a decade plus research horizon can only be justified if sufficient agricultural resources are committed to improve agriculture in the short term as well. In any event, the linkage between ideas and impact on agriculture must be strengthened even more if the diverse groups currently using agricultural resources are to be successful.

LINKING AGRICULTURAL RESEARCH TO THE PRODUCER AND BENEFITTING THE CONSUMER

The State Agricultural Experiment Stations (CSRS) and the State Cooperative Extension Services (ES) provide a framework for linkage from the Idea to Consumer Benefit in the research and implementation process (Figure 1). These institutions originated from separate Federal legislation. The Hatch Experiment Station Act of 1887 emphasized agricultural research and the Smith-Lever Act of 1914 emphasized implementation of that research. These institutions typically became embedded in colleges previously established by the Morrill Land-Grant College Act of 1862. As a result today, agricultural education, research and implementation efforts are intertwined in the bureaucracy and usually in the physical facilities of each State. The State also has the prerogative to provide joint appointments of personnel so that a single individual could be assigned to address all three missions of teaching, research and Extension. This flexibility can address the primary mission in each area given the administrative vision and commitment to support each responsibility in an equitable manner. The major challenge is to balance available resources among these areas so that information developed from research can be carried through to the implementation and educational phases in an efficient and expeditious manner.

Figure 1 illustrates that linkage. A researcher begins with a testable hypothesis because that's the way science operates; this must be clearly understood by everyone if public expectations of agricultural research are to be satisfied. A testable hypothesis is an idea that can be examined. For example "insects damage crops" is a hypothesis but would require examining hundred of crops and thousands of insects to conduct a complete test and few scientists would have the expertise let alone the resources to carry out the work; "pecan nut casebearer damages pecan" is a more manageable hypothesis representing one insect on one crop. Agricultural research on the pecan nut casebearer involves a pecan entomologist, also usually responsible for research on the dozens of other arthropod pests of pecan.

Testing the hypothesis "pecan nut casebearer damages pecan" requires experiments where the insect is given access to some pecans and kept away from others. If significantly more pecans are consistently harvested from pecans where pecan nut casebearers have been excluded, the researcher concludes the pecan nut casebearer is responsible for the yield loss.

Then the general question arises "How can this yield loss be prevented?" There are many possibilities and each requires more research. The pecan entomologist forms a research plan that attempts to both provide an immediate stop-gap solution and that has a long range goal of finding the best solution possible. Stop-gap measures typically use off-the-shelf technology developed by other entomologists in the discipline and are adapted for the pecan nut casebearer by the pecan entomologist. A broad spectrum insecticide applied whenever the damaging stage of the pecan nut casebearer might be present would be an example.

The best solution can be investigated once a stop-gap measure is found. This usually involves developing a precise understanding of exactly how and when the insect causes damage and the determination of what factors reduce or enhance the likelihood of damage. The condition of the pecan, natural enemies of the casebearer and weather are important factors here in addition to the pest itself. As ideas develop, communication must be established and maintained with colleagues in entomology to ensure the work uses the latest approaches, with colleagues in other disciplines to ensure solutions under investigation are compatible with their approaches, with Extension personnel, industry, consultants and producers to ensure solutions can actually be applied, with economists to ensure solutions are economically feasible and with other agencies and consumers to ensure the product will be acceptably produced. This is a time-consuming and often expensive endeavor. Many ideas fail in this process but even a small measure of success can justify massive effort.

The following example from my laboratory illustrates this point. One reason for using this example is that we believe it is typical of the kind of small scale incremental progress that is at work in agriculture. Research on the pecan nut casebearer in collaboration with the people identified above, has resulted in a method to predict when the pest can cause damage, a sampling approach to determine if the pest density warrants treatment, and identification of effective insecticides that can be used in combination with fertilizers and fungicides that are likely to be needed at the same time. Growers using this new technology can reduce treatments from 2-4 to 1-2 treatments per season at an average savings of $20 per acre. There are over 100,000 acres of managed pecan in Texas alone and some 300,000 in the United States giving a potential direct savings to the producers of $6 million annually and 75,000 fewer gallons of insecticide used in the environment. Cheaper production costs means less expensive food and less pesticide means cleaner food and a cleaner environment as well as reducing the likelihood that resistance to the insecticide will develop and render the chemical ineffective.

Realizing the potential of this work requires getting the information to the producer by personal interaction at grower meetings and workshops and cooperation with Extension, consultants, industry and consumers. Time in this area is well spent, but this activity does reduce the time available for additional research that can result in more new and needed technology.

The Cooperative State Extension Service in particular is especially well prepared to participate in taking validated and generalized ideas and integrate them into existing programs all the way to the county level so that their full impact can be made on agriculture. Extension has a network of generalists and specialists who interface between the researchers developing information and the public. Each Extension responsibility is sufficiently broad to require interaction with numerous research programs and user groups, yet hopefully flexible enough to allow a focused impact when new technologies emerge. Extension specialist responsibilities typically are divided by discipline and have two or more commodity assignments like small grains, corn, cotton, cattle, pecan, etc.; but, generalists like county agents cover the entire spectrum of disciplines and commodities in each of their respective counties. Implementation of research information that requires a significant and continuing education component to a large number of users finds this Extension network invaluable.

CSRS AND ES INTERACTION AT THE BENCH LEVEL

CSRS and ES interaction can be illustrated by referring again to Figure 1. The Idea level of agricultural research is a maelstrom of activities ranging from Star Wars-like research to low-risk, fish-in-a-barrel certainties that compete for research resources. The former tend to be long-term and high-risk ventures without current contact with an implementation process whereas the latter are likely to have a target audience and an implementation plan in mind. In both cases, the research must proceed through the validation stage before practical applications can be seriously considered. Other researchers are usually enlisted to generalize the results to the area or world at large and efforts are then turned to integrating the new technology into existing systems. This is a transitional phase between research and implementation that requires tailoring the results to the idiosyncrasies of each real world system and seldom is this an off-the-shelf operation. The specialized researchers know the breadth and depth of the new technology, including its technical limitations, but they are less likely to be familiar with the target audience who will implement this technology. Conversely, Extension personnel know the latter system and, equally important, have the confidence of the target audience, but Extension personnel need to become familiar with the new technology before staking their professional reputations on programs incorporating the new work.

Funding for joint Research-Extension transitional efforts is not always easy to obtain because researchers are reluctant to devote scarce resources to "proven" technologies and Extension personnel are reluctant to adopt "experimental" technologies that may not work in the field environment the same way they performed in controlled studies. This hurdle can only be overcome when strong mechanisms that encourage interactions are in place. Successful CSRS and ES interaction to benefit the consumer occurs when good scientists share the commitment explicitly stated in Figure 1. They achieve excellence when enlightened administrators provide mechanisms to encourage that process and facilitate ways to overcome institutional barriers to getting that job done.

Opportunity for failure in cooperative CSRS/ES work is increasing for the following reasons. Academic credentials of CSRS/ES scientists are better than ever but their backgrounds are increasingly urban so that they lack a hands-on understanding of production agriculture and a natural empathy with producers. This problem stems from both the urbanization of our society and from the expanding umbrella of agricultural research that encompasses new technologies not previously associated with production agriculture. These scientists need to be provided with a clear mission orientation from the highest level. The currency for professional development of research scientists is scholarly publication and that of Extension is program development and delivery. These criteria are sound but need to be combined so that professional development of scientists in production agriculture is examined and rewarded in the context of the overall mission. CSRS and ES formula funding arrives and is accounted for sparely at the State level. This can impede interaction when already scarce resources need to be committed to the interface activities in Figure 1. The worst case scenario at present occurs when personnel are hired and housed separately and distinct lines are drawn between the missions. Finally, and perhaps most importantly, agricultural priorities developed at the Federal level usually reflect either CSRS or ES missions and resulting programs have significant barriers that discourage interaction by not allowing co-CSRS/ES principal investigator's on grants, establishments of guidelines that essentially demand either scholarly publication or program delivery, but not both, and not allowing funding to be shared.

Given these impediments to interaction, some attention should be given to why the existing system works as well as it does. The primary reason is the commitment of scientists to their respective disciplines as they relate to science, agriculture and society. The role of the discipline is a driving force in motivating scientists. The complementary disciplinary structure of CSRS/ES is precisely what allows scientists at the bench level to interact in an atmosphere of mutual respect and to share a common commitment to the mission embodied in Figure 1 despite the obvious institutional, funding and administrative barriers inherent in the system. Interdisciplinary respect and cooperation results from shared perceptions of challenges and needs between disciplines and often a commodity responsibility ties these diverse scientists together in productive albeit *ad hoc* teams. The entire system could be strengthened by supporting disciplines and encouraging interdisciplinary and interinstitutional interactions to a greater extent.

NEW ROLES FOR CSRS/ES INTERACTION

The expanded mission of *reliably producing low-cost more abundant high quality food and fiber at less cost with minimum adverse effects on the environment* has expanded the breadth of production agriculture dramatically in recent years to embrace disciplines and create subdisciplines where none existed before. The reasons for this expansion are a recognition by agricultural institutions of the increased opportunity for new knowledge to improve agriculture and benefit consumers, and increased pressure from forces largely external to agriculture that question the quality and reliable production of our food and fiber and the quality of the environment that results from present practices. Most new resources have been directed at these opportunities and concerns looking for seminal breakthroughs in research. We need new knowledge and we need the means and the direction to implement it. The conventional CSRS/ES bench scientists are the vehicles that have and we believe will catalyze agricultural change by adapting and integrating seminal breakthroughs into the production agricultural system.

Old roles emphasize hardware like hybrid seed or animals, mechanization and application of chemical fertilizers and pesticides. These will continue to be important. New roles will emphasize software approaches where decision-making adds to reproduction agriculture will predominate. For example, insecticides originally protected human valued resources by prophylaxis. Research found new chemicals and Extension advocated their use. Today, problems of insect resistance to insecticides coupled with environmental concerns causes research to seek solutions that minimize their use and Extension to deliver these complex programs. Genetic engineering provides a look into the future with the prospect of transgenic plants that incorporate insecticidal toxins in their tissues. Optimists unfamiliar with the genetic plasticity of insects expect this to be a panacea for insect control. It is clear to the agricultural bench scientist familiar with pests and toxins that the transgenic pest resistant plant emerging from the laboratory of the molecular biologist will require an as yet unspecified management program to be effective in the field. The transgenic plant will be vulnerable to pests developing resistance to it, to take the simplest example, and the manner in which the plant is deployed will determine how quickly that vulnerability is manifested. Further research is needed to identify our options regarding how to adapt this new tool to the field and how to integrate it within the agricultural production system. This is but one example where our broadened research efforts provide new tools that need to be integrated into production agriculture.

The new roles for CSRS/ES bench scientists will be in adapting this information for use and developing programs that work to improve production agriculture and benefit the consumer. The fulfillment of this mission can no longer be accomplished by just concentrating on bringing programs to the county agent/farmer interface where the technical transfer of new information occurs. The increasing sensitivity of the consumer to how we conduct production agriculture is readily seen in issues like medfly eradication in California and the use of Alar™ on apples. A new coalition is needed to mobilize the frustrations of producers and consumers into productive actions that capitalize upon the expertise, linkage and commitment to production agriculture shown in Figure 1. The CSRS/ES bench scientist has the skill and desire to improve this process. Support is needed to coordinate the efforts of scientists and to interface their abilities with nontraditional segments of society consisting of environmentalists, concerned consumers, etc. to plan, conduct, evaluate and implement research that truly meets consumers needs. The bench scientist has a crucial role to play in this process in developing the scope of research, communicating the range of possible solutions to the production agriculture and consumer community, formulating those programs that offer the greatest promise and delivering those successful programs to the consumer.

POLICY RECOMMENDATIONS

1. An explicit recognition should be made of the expanded CSRS/ES mission of reliably producing low-cost more abundant high quality food and fiber at less cost with minimum adverse effects on the environment.

2. The consumer should be explicitly recognized as the ultimate target of CSRS/ES efforts and provisions should be made to obtain input by including consumers as well as traditional representatives in planning and programming efforts.

3. Institutional barriers to CSRS/ES cooperation should be recognized and ameliorated by encouraging joint appointments and formation of research/Extension teams that allow principal investigator interchangeability, resource sharing and a broader view of professional development.

4. New resources and programs should be developed that support the CSRS/ES interface between the completion of validated research and demonstrating that work in the producers field to a consumer audience.

FIGURE 1. An outline of the linkage from an idea to having an impact on agricultural production and benefitting the consumer.

General Objective: To reliably produce cheaper more abundant high quality food and fiber at less cost with minimum adverse effects on the environment.

Specific Objective: Participate in one or more phases of the research/Extension process and maintain a commitment to the general objective.