SAVING THE SEED OR SAVING ROMANTIC ASSUMPTIONS: Eco-Myth or Agricultural Reality?*

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Modern agriculture has become a villain of choice for many who find the trends of the last half of the 20th and beginnings of the 21st century to be ecologically destructive if not life threatening. It is increasingly being used as an all encompassing category by critics of globalization and transgenic (genetically modified) food crops and by street protestors and their mentors and organizers. Implicit in the protest rhetoric is a dichotomy between modern agronomy assumed to be large corporate enterprises (agribusiness), either farming or selling to farmers and small self-sufficient farmers who replant their own seeds from year-to-year and have minimum if any reliance on the market for inputs. SAVE THE SEED has become the battle cry of those who claim to speak for the world's poor. They assert that the vast majority of the world's farmers ONLY plant seeds from their previous harvest as those who went before them have been doing for the several millenniums since agriculture began in their region.

The difference between the two presumed types of agriculture could not be more stark in the minds of the believers. The enemy (MonSatan) is the monopolistic seed corporations and industrial farms that are mechanized, use purchased inputs including synthetic fertilizers and chemical pesticides and are by definition "corporate polluters." In contrast, the small scale traditional agriculturalist follow more benign practices substituting labor for technology and otherwise using more natural time-tested practices and inputs that preserve the soil and do not pollute the environment. Commercial "organic" farmers in developed countries are seen as a permitted exception to the agribusiness category as they are assumed to be following a regimen that is the a larger scale environmental equivalent of traditional agriculture. Even here, among the "organic" enthusiasts, there are purists who bemoan the take-over of the movement by large corporate enterprises and call for buying from small local producers even if the price is significantly higher. To these purists, "organic food is being openly accused of selling its soul" (Vidal 2003).

The idea that agriculture can in any way be "natural" or in "harmony with nature" is silly if not downright pernicious. This does not mean that we are free to do whatever we wish and not be concerned with the consequences. It does mean in transforming nature, we have to acquire a scientific understanding of as many dimensions of agriculture and the environment as possible and then devise and continually revise rules of the game so that we can grow and raise our food sustainably. In agriculture, we are concentrating nutrient that is also nutrient for birds, rats, insects, fungus, bacteria and viruses. In a word we have to protect the plant which historically has required a "pesticide" of some sort or another in addition to the plant's natural defenses. When we grow a plant in one location and eat it in another, we are mining and transporting soil nutrient which has to be replenished. If nature doesn't provide sufficient nutrient in usable form as is the case with nitrogen, then humans have to produce it (Smil 2000 and 2001). Harvesting and eventually transforming plants means that we have to act to maintain their continuity by some form of compensation. According to Wood and Lenné:

> Harvesting of plant parts - particularly the reproductive parts - for human food would decrease the competitive ability of targeted plants. Unless there was some compensation for this, the population of the food plant would decline in competition with non-food plants; there would be less food for gatherers the following season (Wood and Lenné 1999a, 20-21).

They add:

> Simply, if we eat the plant's reproductive strategy, it will not be able to compete with less useful species. To maintain the food supply, we need to compensate the plants in some way. With compensation, the food species could expand at the expense of non-food plants, giving us a more assured food supply (Wood and Lenné 1999a, 21).

To Wood and Lenné, "compensation is the key to the coevolution of food plants and human exploitation" (Wood and Lenné 1999a, 21). After describing the compensatory mechanisms of agriculture, they conclude that "agriculture is therefore a combination of ways in which we help food-providing species to compete making more and more plants dependent on our `sufferance or favor'" (Wood and Lenné 1999a, 21).

The FAO indicates that there are 1.4 billion farmers who save seed for planting from harvest to harvest. Unfortunately, FAO does not distinguish between farmers who never have bought seeds and farmers who go into the market one year and replant it for one, two or more years until a new higher yielding is available or a new disease variety becomes necessary. Nor does it identify the very common practice of poorer farmers in many regions who in replanting their seeds will mix with it anywhere from 40 to 60% of a purchased variety. Even more affluent farmers have for the last 4 decades been crossing modern varieties with local ones providing the Green Revolution seed package far greater diversity than the critics seem to be aware.

Our food supply remains safer than it ever has been. Proponents of "organic agriculture" and many consumers believe that "organic agriculture" is "pesticide free" in spite of the fact that there is a USDA website for approved pesticides for "organic agriculture" including synthetic pesticides (USDA 2002, http://www.ams.usda.gov/nop/NationalList/FinalRule.html). Purists who oppose "transgenic" plants because it is somehow "unnatural" nevertheless have yet to my knowledge raised any objections to plants that are the result of mutation breeding using carcinogenic chemicals or gamma rays or the use of techniques such as altering the ploidy or chromosomal structure by crossing diploids and haploids, tissue culture or somoclonal variation, embryo rescue, protoplastic cell fusion etc. Of course, if they did object, they would have problems finding anything to eat. And we must never forget that these mutation-bred plants are very much a part of the crops of the "organic" farmers whose supposed opposition to synthetic pesticides requires them to use varieties that are more resistant to disease infestation. Yet these same farmers oppose the transgenic plants (particularly when used in conjunction with conservation tillage) that have most effectively provided pest resistance increasing output and reducing pesticide use as well as reducing fuel use, water loss, soil erosion and conserving biodiversity. The fear is the transgenic resistance genes will outcross with the non-food crop plants or transfer resistance genes to a bacteria ("jumping genes"). Breeding in genes for resistance by means other than transgenics seems to arouse no fears that these same genes will outcross with weeds creating so-called superweeds that are no longer deterred by the pesticides. (For the last 40 years, hundreds of millions of hectares have been planted in modern varieties of wheat and rice and yet there is not a single verifiable case of a dwarfing gene migrating to neighboring species.) Without question, gene flow from transgenic crops will happen in one form or another as it has happened with planted crops since the beginning of agriculture. Critics argue that inserting a gene from one species to another is "unnatural," nevertheless then raise fears that the transgene will in nature jump to other species. (We should add that the restriction endonucleases and ligases [both are enzymes] used to cut and re-ligate the cohesive ends of DNA for recombinant DNA technology were first **observed** in nature as were the plasmids [circular pieces of DNA outside the chromosome] as a means to encode a genes. They were not the product of mad scientists.) What basis then in fact or theory is there to call gene flow from transgenic crops, "contamination?"

"Defying the expectations of scientists monitoring transgenic crops such as corn*** and cotton that produce insecticidal proteins derived from Bacillus thuringiensis (Bt), target insect pests have developed little or no resistance to Bt crops thus far, according to US Department of Agriculture's funded scientists" (Fox 2003, 958, see also Tabashnik et al. 2003a&b and Mendelsohn et al. 2003). Ironically, the diamondback moth "evolved resistance to Bt sprays used by organic growers, but no pest has evolved resistance to transgenic Bt crops in the field" (Fox 2003, see also DeGregori 2003a, 115-116). The irony is of course that it is the organic growers who have vociferously complained that the transgenic Bt varieties would lead to the emergence of super bugs resistant to their Bt spray. The question then is - who owns nature - particularly when an ownership claim is made by those who oppose patenting life forms (Brown 2003).

Then there is the fear that transgenic genes will move about genome, land in the wrong place or interact with other genes leading to the expression of other characteristics (called pleiotropy) such as a dangerous toxin or allergen. Barbara McClintock won the Nobel Prize in 1983 for her discovery of chromosomal instability fifty years ago. Plant geneticists have yet to observe any greater chromosomal instability in transgenics but they have in the products of tissue culture which has been absolutely essential, particularly in developing countries for breeding plants resistance to a particular disease.

> The use of tissue culture in plant breeding has also often resulted in somaclonal variation of plant lines and irregular phenotypes or field performance. Somaclonal variations are mutational and chromosomal instabilities of embryonic plants regenerated from tissue cultures

(Haslberger 2003).

Unfortunately, these "chromosomal instabilities" persist for some time not only in the original crop but in future crops in which it is part of the breeding stock.

These instabilities may result from activation of dormant transposons in the chromosome. The consequent genetic variability is known to persist for many generations and is difficult to eliminate by backcrossing (Haslberger 2003).

It is interesting to note that in searching for the possible "unintended consequences" of rDNA. a committee of the Codex Alimentarious found the most serious unintended outcomes were in crops from "traditional breeding."

a traditionally bred squash caused food poisoning, a pest-resistant celery variety produced rashes in agricultural workers (which was subsequently found to contain sevenfold more carcinogenic psoralens than control celery) and a potato variety Lenape contained very high levels of toxic solanine (Haslberger 2003).

These crops are no longer cultivated (Kirschmann and Suber 1998, Ames and Gold 1990a and Prakash 2001). The most recent episode was an outbreak of "killer zucchini" which produced the "only food scare in recent history in New Zealand" and interestingly it "stemmed from the farming methods of organic farmers and others who use unconventional farming practices" (LSN 2003). In February 2003, Zucchini with "high levels of natural toxins" were sold on the vegetable market and resulted in "several recorded cases of people suffering food poisoning" (LSN 2003). We often worry about the toxicity resulting from spraying crops but rarely are concerned from those from not spraying them.

An examination of common factors shows the levels of toxin apparently increased among zucchini growers who did not spray their crops. Unusual climatic conditions meant there were huge numbers of aphids about in January and insect predation is sometimes associated with increased levels of toxins in plants (LSN 2003).

In this case, there was a "clear link between increased toxin levels and older open-pollinating varieties of seeds" (LSN 2003). It is "likely zucchini grown from saved seed will therefore be more vulnerable to toxin build-up" (LSN 2003). The scientists who reviewed the "killer zucchini" case were very clear that the "most likely cause of the build up of toxins is a genetic weakness in older varieties." However worthy the farmer's intentions may have been, "the growers' decision to use older varieties and to save seeds is likely to have resulted in a health risk for consumers - something which has never happened with crops derived from genetic modification" (LSN 2003).

The work of Bruce Ames and two different National Academy of Science studies has shown that over 99.9% of the toxins that we ingest are the natural products of plants and most of them are rodent carcinogens (Ames et al. 1990a&b, NAS 1973 and NRC 1996). With rDNA, conventional farmers are able to mass produce better protected food with fewer toxins in the plant and on it. Transgenic crop breeding is the most predictable form of plant breeding ever devised by humans and is therefore the safest. Yet it is also the only form of plant breeding that is regulated, largely because it is the only form of plant breeding for which it is reasonably possible to test prior to widespread use. (Using rDNA to create plants that express a vaccine or pharmaceutical has tremendous potential for benefiting those most in need. However, given the many possibilities of harm, this for of transgenics most operate in terms of very strict protocols, careful segregation in growing and strict oversight and regulation.)

Gail Omvedt speaks of a "a distorted image of farmers held by a section of the urban elite" in India as well as in developed countries. This mythic image:

> depicts them romantically but demeaningly as backward, tradition-loving, innocent and helpless creatures carrying on their occupation for love of the land and the soil, and as practitioners of a "way of life" rather than a toilsome income-earning occupation. These imagined farmers have to be protected from market forces and the attacks of multinationals, from the seductions of commercialization and the enslavement of technologies (Omvedt 1998).

My experience has been the opposite to the SAVE THE SEED activists in that I cannot recall encountering farmers who voluntarily fit the SAVE THE SEED definition of a "traditional farmer." I have met with farmers who wished to plant a better, higher yielding variety but were uncertain whether the credit or fertilizer or pesticides would be available to them in time. Even without the additional inputs, the farmers recognized that the improved seed would give them a better crop but not enough better to warrant the expenditure for the seeds. I add this because one of the slogans of those critical of Green Revolution is that the HYV (high yielding varieties) seeds "require" more fertilizer, water and pesticides when in fact they outperform the traditional varieties at most any level of inputs (for a recent example of the "require more" thesis, see Webb 2003).

> The modern rice varieties have about a threefold increase in water productivity compared with traditional varieties. Progress in extending these achievements to other crops has been considerable and will probably accelerate following identification of underlying genes (FAO 2003, 28).

The FAO adds:

> Genetic engineering, if properly integrated in breeding programs and applied in a safe manner, can further contribute to the development of drought tolerant varieties and to increase the water use efficiency (FAO 2003, 28).

Overall, The best estimates are that "the water needs for food per capita halved between 1961 and 2001" (FAO 2003 28).

Higher yields "require" more fertilizer as the more nutrient that is extracted from the soil, the more that has to be replaced. Norman Borlaug in his Nobel Prize acceptance speech states: "If the high-yielding dwarf wheat and rice varieties are the catalysts that have ignited the Green Revolution, then chemical fertilizer is the fuel that has powered its forward thrust ... The new varieties not only respond to much heavier dosages of fertilizer than the old ones but are also much more efficient in their use" (Borlaug 1970).

The old tall-strawed varieties would produce only ten kilos of additional grains for each kilogram of nitrogen applied, while the new varieties can produce 20 to 25 kilograms or more of additional grain per kilogram of nitrogen applied (Borlaug 1970).

Not only are the Green Revolution plants more efficient in fertilizer use but equally important has been the improvement in the use and application of fertilizer. For example, there has been a 36% increase in "N efficiency use in maize"*** the United States over the last 21 years as a result of improved knowledge and technology (Blair and Blair 2003). Even Europe with its obscenely ridiculous agricultural subsidies and the environmental problems resulting from over use of fertilizer, has seen yields rise faster than fertilizer application (Fresco 2003). Imagine the potential increases in efficiencies that could be realized if the agricultural subsidies in Europe and the United States were removed. In other parts of the world such as Latin America and Africa, the problem is not too much fertilizer but not enough. Genetic engineering offers further opportunities for more efficient fertilizer use by increasing the photosynthetic efficiency of plants (Surridge 2002, 577).

In Latin America and the Caribbean, the "nutrient balance is negative for most crops and cropping systems."

The end result is not just loss of soil fertility. The physical and biological structure of the soils will also be degraded including reduction in soil organic matter levels and hence of carbon sequestration, lower moisture holding capacity and greater vulnerability to erosion (Norse 2003).

Synthetic nitrogen fertilizer costs money, so as one would expect, farmers attempt to become more efficient in its use. The best measure of this is the ratio of nitrogen in the fertilizer applied to the nitrogen in the crop. This ratio fell for American farmers by 2% a year from 1986 to 1995. Further, there is no evidence that bulk deposition of nitrogen, which is of environmental concern because of run-off into rivers and streams, has been increasing (Frink et al. 1999). Another measure of increasing efficiency in nitrogen use is the feed-to-meat ration. As we have just shown, the synthetic nitrogen-to-nitrogen in the crop has been falling and now, in turn, the "calculated feed to produce a unit of meat fell at an annual rate of 0.9%" from 1967 to 1992 (Waggoner and Ausubel 2002). With increasing crop yields per acre, "cropland for grain-fed animals to produce meat for Americans shrank 2.2% annually" (Waggoner and Ausubel 2002).

It is important to note here that the global demand for animal products - meat, milk, cheese, eggs, chicken etc. - is increasing at a faster rate than population and the basic demand for food. For example, while grain production was increasing 2.7 times over the last forty years, production of broiler chickens increased slightly more than six times from 8 billion to 49 billion. More efficient cultivation of maize as an animal feed will be an essential component for continuing to provide the nutrients that are improving the health for much of the world's population. As an historical note, the diffusion of maize into Europe following its maritime contact with the Americas, is credited with providing the yield necessary for expansion of animal production and consumption which in turn is considered an important causal factor in the expansion of life expectancies that followed (Scott and Duncan 2002).

Even before the Green Revolution dramatically increased the demand for and use of synthetic fertilizer, there was a large difference between the nutrients extracted from the soil in India and the "organic" nutrients available to be returned to it. In the 1960s, each year cultivated crops in India were removing:

> 3 million tons of nitrogen, 1.5 million tons of phosphorus oxide and 3.5 million tons of potash...8 million tons of plant food. The organic sources of the plant food returned to the soil is hardly 1.8 million tons of nitrogen, 0.60 tons of phosphorus oxide and 1.8 million tons of potash...4.2 million tons of plant food (Randhawa 1983, Vol.3, 314-317, using data from Agarwal 1965, 7, 12, 13, 14, 214)

Randhawa adds: "Even allowing for the biological and other natural processes for recuperation of fertility, the balance ie tremendous" (Randhawa 1983 317). Nearly twice as much nutrient was being withdrawn from the soil than was being returned. This process was not sustainable. Given the dramatic increases in Indian agricultural output over the last four decades (which more than accommodated a doubling of the population), the deficit in "organic" nutrient must be vastly greater today.

Similarly for Africa:

> Soil fertility depletion on smallholder farms, together with the concomitant problems of weeds, pests and diseases, is the fundamental biophysical root cause for declining per capita food production in sub-Saharan Africa (Kelemu et al. 2003, see also Sánchez et al. 1997).

The annual loss of nutrient in Africa is "equivalent to US$4000 million in fertilizer." These are rates of nutrient depletion that "are several times higher than Africa's (excluding Rep. of South Africa) annual fertilizer consumption, which is 0.8 million t N, 0.26 million t P and 0.2 million t K" (Kelemu 2t al. 2003, see also FAO 1994 and Smalling et al. 1997). The "traditional way" of overcoming soil nutrient depletion by applying mineral fertilizer is rendered difficult by fertilizer cost which is "2 to 6 times as much as those in Europe, North America or Asia" (Kelemu et al. 2003). Thus there is a need to use the tools of modern plant molecular biology to develop cultivars that are more efficient in nitrogen use (Rao and Cramer 2003, see also ECA 2002).

The Green Revolution seeds turn out to be more disease resistant (as plant breeders have added multiple disease resistant genes - gene stacking) requiring less pesticides. "Increasingly, scientists breed for polygenic (as opposed to monogenic) resistance by accumulating diverse, multiple genes from new sources and genes controlling different mechanisms of resistance within single varieties (Smale 1997, 1265, see also Cox and Wood 1999, 46). The coefficient of variation for rice production has been steadily decreasing for the last forty years which would seem to indicate the new technologies in agricultural production are not as fragile as some would have us believe (Lenné and Wood 1999, see also Wood and Lenné 1999a&b and Evenson and Gollin 1997). This has also been the case for wheat. "Yield stability, resistance to rusts, pedigree complexity, and the number of modern cultivars in farmers' fields have all increased since the early years of the Green Revolution" (Smale and McBride 1996).

Modern "monoculture" is central to the unverified claims about modern varieties being less disease resistant (DeGregori 2003c). The "natural ecosystems" from which important cereals were domesticated were often moncultures - "extensive, massive stands in primary habitats, where they are dominant annuals." This includes the "direct ancestors of our cereals **Hordeum spontaneum** (for barley), **Triticum boeoticum** (for einkorn wheat) and **Triticum dicoccoides** (for emmer wheat)" which "are common wild plants in the Near East" (Wood and Lenné 1999, 445). This was not unique to the Near East but was a prevailing pattern of the time. In the transition from Pleistocene to the Holocene, "climatic changes in seasonal regimes decreased diversity, increased zonation of plant communities, and caused a shift in net antiherbivory defense strategies" (Guthrie 1984, 260). The "ecological richness of late Pleistocene" in many of the areas that humans were first to develop agriculture, gave way to "relative ecological homogeneity during the succeeding Holocene" (Guilday 1984, 251). As the ecological mosaic shifted "from plaids to stripes" creating zones of greatly reduced plant species diversity, the animal life that the habitat supported was similarly transformed. "As the plant communities became more zoned, there were fewer optimal `plaid' mixtures of plants for the species requiring nutritional diversity in their diet" (Guthrie 1984, 282).

Critics of modern agriculture who fear the susceptibility to disease from monculture, continually hark back to the southern corn-leaf blight in the U.S. in 1970 since they can not come up with any other comparable loss in the last half century in corn or wheat or rice, the staples that provide about two-thirds of the world's food production. The $1 billion in losses of about 15 to 25% of the 1970 corn crop was substantial but these loses should be considered against the fact that corn yields had more than doubled over the previous two decades and that the crop year following the blight was one of record yields. When not using the corn blight, the critics go back over 150 years to the Irish potato famine. And they simply ignore the crop losses and famine that have been the lot of humankind since the begining of conventional, largely "organic" agriculture.

It is interesting to note that the 1970s corn blight resulted from actually trying to introduce an element of diversity to the corn plantings as has been done successfully in other grain crops. In the corn blight case, "susceptibility to blight is conditioned by the mitochondrial genome" (Parrott).

> Maize with one genotype of mitochondria, called T cytoplasm (Texas male sterile) turned out to be susceptible to the blight fungus. Prior to the introduction of the T cytoplasm, all the maize had N (normal) cytoplasm. In this case, switching from one cytoplasm genotype grown throughout the

> country to two cytoplasm genotypes is what allowed the disease to develop: increased cytoplasmic diversity allowed disease to develop (Parrot 2003).

Wayne Parrott adds: "Needless to say, we are back to the one cytoplasm which has been stable for centuries." From the first work in wheat in Mexico, it was clear that a Green Revolution yield increases depended on both increases in plant production as well decreases in crop losses. Since then, some of the most important and widely planted high-yielding varieties (HYVs) were bred from a multiplicity of varieties from different countries creating varieties that were and are multiple-disease resistant but also were better able to withstand other forms of stress. Most critics do not seem to realize that the Green Revolution was not a one shot endeavor for wheat and rice but an ongoing process of research for new varieties and improved agricultural practices. In addition to the planting of disease resistant varieties, there is an international network of growers, extension agents, local, regional, national and international research stations, often linked by satellite that has successfully responded to disease outbreaks that in earlier times could well have resulted in a global crisis. Historically, the farmer had access to a limited number of local varieties. Today, should there be a disease or other cropping problem, the farmer can be the beneficiary of a new variety drawn from seed bank accessions that number into the 100s of thousands for major crops like rice. Increasingly, farmers may have the benefits of a variety with a transgene from another species. Monoculture defined in terms of being widely planted crops is in fact not only consistent with an incredible diversity of means for crop protection, it is the sin qua non for them because it is not possible to have such resources for all the less widely planted crops. [Targeted genome sequencing by methylation filtration offers a lower cost method for gaining valuable information for plant breeding about food crops where the more expensive approach of sequencing the entire genome might not be financially warranted (Palmer et al. 2003 and Whitelaw et al. 2003).]

Contrary to the doomsayers, some of the modern commercial plant varieties that have had resistance genes bred into them have maintained this resistance for long periods of time - up to 50 years in some cases - and are still functioning well.

> In the United States, the T gene in barley has held up against stem rust for over 50 years; similarly, in wheat the Hope gene has kept stem rust in check for over 40 years and the LR-34 gene has limited leaf rust for more than 20 years (Sanders 2001).

To Sanders, "multiple-gene resistance and other techniques are preferable when they are available" but we "use what we have if it works, and we anticipate breakdowns" (Sanders 2001). This pragmatic process of breeding in plant protection is not only vital for agriculture; there is no alternative to using a variety of modern crop protection strategies.

For an understanding of modern agricultural ecosystems, Wayne Parrot has the right "take-home message."

> built-in disease resistance is the most reliable and economical method to achieve stable crop yields, be it under

> monoculture or polyculture conditions. These resistances can be bred in from wild relatives or obtained via recombinant DNA technology (Parrott 2003).

Parrot wisely adds:

> Ultimately though, evolution is a dynamic process, so the job of resistance is never done. We may achieve disease protection which will last anywhere from a few years to several centuries, but ultimately, I would not consider anything as permanent (Parrott 2003).

If one seeks to understand plant diversity at the genomic level, an argument can be made for increased diversity. "Some modern varieties of rice and wheat have very comprehensive pedigrees and can be highly genetically diverse. For example, `IR 66' has 42 landraces in its parentage with multiple disease and pest resistances, drought tolerance and earliness" while another variety has 49 landraces including multiple disease and pest resistances (Hargrove et al. 1988, cited in Polaszek, Riches and Lenné 1999, 288). Thanks to modern plant breeding, wheat has a diversity which it previously lacked. "Wheat lacks diversity because it evolved through a **natural** genetic bottleneck. It has always teetered on precariously narrow genetic base" (Cox 1998, cited in Cox and Wood 1999, 44-45). Bread wheat was the accidental "unnatual" crossing of einkorn and then emmer wheat with another species. The latter, tetraploid emmer wheat (**Triticum turgidum**) somehow crossed with a weedy diploid goatgrass (**Aegilops tauschii**) (Cox and Wood 1999, 45). What was done by nature could not be done by humans until we could grow rescued embryos in an artificial medium. Modern wheat now has a number of resistant genes that have been derived form other species giving it a greater diversity and vastly greater disease resistance. And this increased resistance has produced results.

In their study of the "wheat's origins and the flows of germplasm between various regions of the world," Smale and McBride examine "patterns of bread wheat diversity in farmers' fields and evidence of genetic variation from breeding programs."

> Findings suggest that the often-invoked dichotomy between the gene-poor North and the gene-rich South has little validity for wheat. Findings also suggest that yield stability, resistance to rusts, pedigree complexity, and the number of modern cultivars in farmers' fields have all increased since the early years of the Green Revolution (Smale and McBride 1996, Abstract, see also CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). 1996, Rice et al. 1998, Smale 1997, Smale, ed. 1998, Smale et al. 1996 & 2002 and Gollin and Smale 1998).

Paddy farmers (rice in the lowland fields is called paddy, in the market or on the table, it is rice or the equivalent in the local language) in Asia regularly go into the market for high-yielding varieties of seeds as well as other inputs. The paddy farmer who wishes to save seed from the previous harvest for a planting, will have to go back into the market from time to time for new disease or insect resistant varieties. Even the proverbial traditional farmer will have occasionally to go into the market to buy seeds in order to break a cycle of plant disease or weed infestation which are perpetuated by planting from the previous harvest. My first encounter with agriculture in a developing country was four decades ago in 1962 in the Gezira scheme in the Sudan in Africa. There the farmers in an agricultural scheme irrigated by the Blue Nile were required to buy cotton seeds that were grown over a thousand miles away in a delta on the Red Sea. Farmers not only did not replant their own seed, they were not allowed to do so and were even required to dig up the roots of the cotton plants in rock hard soil and burn them in the blistering sun in order to keep disease under control. This requirement was not out of any bureaucratic or authoritarian impulse but a necessity to prevent an outbreak of a disease which had the potential of destroying the entire crop for everyone in the project.

Some of the reasons that farmers do not replant their own seed or would prefer not to do so if an alternative was available:

1) Disease is carried over from one crop to another as are the seeds of competitors. Ironically, one often finds that commercial farmers in developed countries are often more able to save seed from year to year because of better disease management and safer storage.

2) Post harvest loses - Nobody to my knowledge has trained rats, insects and microorganisms to distinguish between the crop that farmers store to eat and that portion which will be saved for replanting the next year providing all of them with continuing life sustaining nutrients.

3) Genetic deterioration even without an understanding of all the mechanisms of replication, most farmers recognize that inbreeding a crop can lead to a deterioration of it over time (Heisey and Brennan 1991 and LSN 2003). Even some the farmers who might fit the SAVE THE SEED definition of being traditional, will exchange seeds among themselves.

4) Where the climate permits, farmers will plant a succession of crops, sometimes it will be different varieties of the same crop. They may plant an IRRI (International Rice Research Institute) variety of rice when irrigating and a domestically bred variety for a monsoon crop. And they may have a third crop of an entirely different food crop. Saving the seeds for three different crops plus possibly those for the kitchen garden is not always easy or convenient.

5) Contrary to the slogans of the urban white European and North American males who dominate the activists movement, farmers are not naive simpletons in need of the protection of those who know nothing about raising food. Farmers actively seek for crop improvements such as higher yields, disease resistance or improved quality and marketability. Remember the doomsday predictions about the Green Revolution? Even the most techno enthusiasts among us (like myself) had to be more than mildly and pleasantly surprised at the speed and extent to which farmers

defined as "traditional" adopted the Green Revolution technological package where credit, extension etc. were available.

6) Farmers in Africa (where farmers most closely resemble the activists definition of traditional or to put it differently, if farmers anywhere are to fit the activist definition, it would be in sub Saharan Africa) where many have switched to hybrid maize making it a major food crop (Byerlee and Eicher 1997). Hybrid maize essentially requires annual purchase of seeds as hybrids do not breed true to form in the field.

7) Cleaning seeds and coating them with pesticides is often the most efficient form of pest control and it can be done safely and better by professionals.

8) Ironically, saving seed from harvest to harvest is on the increase in Europe where many of the urban SAVE THE SEED activists live because European farmers have a higher level of crop protection reducing the possibility of carry-over diseases and have access to mobile seed processors who can do the necessary on-the-farm seed preparation impossible in most poorer regions. In the region with militant advocates for the immutable farmers' right from time immemorial to replant their own seeds, farmers are required to pay fees for using their own seed where that seed is protected by plant breeders' rights. The 1994 European Union's legislation allowed farmers to pay a "sensibly lower remuneration" for the use of farm saved seed. These fees are collected in the United Kingdom by "farmers' unions and mobile seed processors, who are contracted to collect the farm saved seed payments. Mobile seed processors move from farm to farm cleaning and treating farm saved seed for farmers" (Turner 2003).

Some farmers or farmers in some regions specializing in seed production for planting by other farmers has a much longer history than most of us realize. According to Tripp, "trade in seed is literally as old as agriculture" while "formal commercial seed trade is hundreds of years old" with a least one recorded instance as early as 1296 in the England and Scotland (Tripp 2001, 36).

By the middle of sixteenth century markets and shops in London were supplied with a range of vegetables and pulse seeds by growers who specialized in seed production. A pamphlet from a seedman in 1732 describes seed imported from Italy, Turkey, Egypt, France, Holland and Brazil (Tripp 2001 36).

In the post Civil War period, the US Department of Agriculture and land grant agricultural institutions were providing new varieties of many important crops while state extension services were encouraging the formation of agricultural associations. Private and public research using the emerging knowledge of biological replication and evolution were producing improved varieties. Before then, the US government had gone overseas to seek varieties of wheat that would grow in the new territories that were being settled. By the 1890s, the US government was sending out millions of packages containing packets of several different seeds each year. The era of commercial seed companies came to the forefront with the development of hybrid maize (Tripp 2001, 36-37).

Going into the market to buy inputs generally but not always means going into the market to sell some output. As this is being written, changes are underway that are rapidly diminishing the numbers that fit the romantic category of traditional farmers. In India and China, an increasing percentage of their rice output is the result of a new complex, sophisticated form of hybridization while farmers in the Punjab in India who have been growing high yielding varieties of wheat are now growing even higher yielding hybrid varieties and wheat farmers in China are expected to follow with new hybrids produced by their government. And may we add that there is greater genetic diversity in the wheat planted in the Punjab today than was the case a half century ago prior to the Green Revolution.

In the Indian Punjab in the 1950s, "the area planted to a single cultivar was high. ... In the high potential zones, semidwarf wheats generally replaced the tall cultivars that had been released by the Indian national breeding program from the early 1900s ... if any long term trend is observable since 1947, it has not been upward" (Smale 1997, 1261). Citing Howard and Howard, Smale adds that "according to government records, Indian landraces, which were planted to millions of contiguous hectares, were notably susceptible to rust. Average annual losses were estimated in one document at 10% of the value of the crop" (Smale 1997, 1261).

Hybrid maize has become an increasingly important crop with maize production expected to exceed that of other grains sometime in the next twenty years. Of the roughly 200 million maize farmers in the world, circa 98% are in the developing world. In many developing countries, hybrid maize has become "the predominant seed type ... for example 84% of the 105 million Chinese maize farmers buy hybrid seed, and 81% of all maize seed used in Eastern and Southern Africa is hybrid" (James 2003).

In spite of vociferous opposition, the planting of transgenic crops is increasing worldwide, more in developed countries than developing countries, as farmers find that higher final output from either increased yield or reduced crop loss or both, makes it worthwhile to pay a premium for commercial transgenic seeds.

Some of the farmers who most closely fit the idealized concept of "traditional" are engaged in agricultural practices that are anything but environmentally benign. The author's experience with upland rice farmers in a Southeast Asian country is indicative of some of the complex problems facing "traditional" farmers and those seeking to encourage more environmentally sustainable practices. Throughout Asia, farmers are planting upland rice on cleared hillsides that are subject to rapid erosion and with yields that have changed little over the last forty years while those of their lowland neighbors in paddy have seen their annual output at least triple. Those with whom the author has been involved were gaining a very meager subsistence from their plot which they supplemented with two to three days labor in the local village or nearby town. Most if not all were aware that their farm was rapidly eroding with their very modest yields declining as their farm would eventually be totally denuded. Their response was simple and logical - the farm fed their family and their off-farm employment provided for school fees for their children and other necessities. By the time their land was no longer arable, their children would be grown and employed elsewhere, they could then get by on the income from the occasional paid labor. (Over half the farmers in Java obtain over half their real income off-farm. This is increasingly the case in the United States also.) When an aid development worker proposed substituting a bush or tree crop such as papaya that would protect the soil, their negative response was equally simple and logical. Like the vast majority of the world's agriculturalists, the farmers lived in a village apart from the farm. Night raiders are unlikely to try to harvest a rice crop but they could clean the trees of their entire output. Anyone who travels throughout the Third World will see the fruit trees and kitchen gardens tightly packed around the village households for precisely this reason.

Clearly with the upland farmer yield was a critical factor. It is low yields and low incomes and limited opportunities which force the poor to farm the hillside or cut down rainforest or otherwise bring land under cultivation land that is marginal for agriculture. Low yields perpetuate themselves in a vicious cycle of low yields and continued poverty and environmental degradation of all kinds. After the furor over the alleged threat to the Monarch butterfly from transgenic maize was shown to be a tempest in the teapot, it is clear that the most serious threat to the Monarch butterfly is from the destruction of its winter forest habitat in Mexico by poor farmers clearing small plots to raise crops to feed their families. Higher sustainable yields on existing farms including the use of transgenics and/or more rewarding non-farm employment would greatly aid the protection of the forest habitat and the preservation of the Monarch butterfly.

Whatever the environmental problems of the much maligned Green Revolution technologies in wheat and rice, and they are real, the increase yields from these and related gains from modern agronomy in other crops such as hybrid maize have had the effect of minimizing the amount of land that had to be brought under cultivation. It is widely understood that the single most important cause of species extinction is loss of habitat. In the last forty years of the twentieth century, the world's population slightly more than doubled from about 3 billion to over 6 billion people while global food supply increased to about 270 percent of its 1960 level resulting in a 30 to 40 percent increase in per capita output. This was achieved even though the land under cultivation increased from 1.4 billion hectares to only 1.5 billion hectares.

the yield-increasing, land-saving nature of the Green Revolution

> has **reduced** the pressure to put more land under the plow. Indeed, the recent data bear out this interpretation: Indian food grain output has continued to grow at a healthy rate of 3 percent annually through ... 1981-1991 while the land under cultivation has actually decreased annually (Nanda 2003, 243 citing Sawant and Achuthan 1995; Hanumantha Rao 1994).

The enhanced Green Revolution yields in the primary food/calories source, makes more land available for a variety of other crops and greater diversity in the population's diet. This is counter to the conventional wisdom about the Green Revolution and its impact upon diet and nutrition. Sawant and Achuthan found the "decisively superior performance of non-foodgrains **vis-a-vis** foodgrains" to be the "most striking feature of India's agricultural growth in the recent period (Sawant and Achuthan 1995, A-3). For 1981-1992 in India, the compound annual growth rates (CAGR) of non-foodgrains of 4.3 per cent "exceeded significantly that of foodgrains" at 2.92 per cent. Though there was annual decline of 0.26% in the area of foodgrain cultivation, "it is important to recognize that foodgrains output continued to grow at the rate of 2.92 per cent as the growth in yield per hectare exceeded 3 percent" for a CAGR of 3.19 per cent, all of which indicates an "an increasing shift of land from foodgrains to non-foodgrains" (Sawant and Achuthan 1995, A-3). "The entire output growth in this period can, therefore be attributed to the increase in yields per hectare" (Hanumantha Rao 1994, 12).

> The most important contribution of technological change in Indian agriculture since the mid-sixties consists in making Indian agriculture progressive and dynamic by making farmers increasingly conscious of science and technology (Hanumantha Rao 1994, 51).

After surveying a wide range of crops in India, the Sawant and Achuthan conclude that there is "evidence in support of a wider, greater diffusion of technology in recent years to a large number of crops not benefited in the early phase of the green revolution" (Sawant and Achuthan 1995, A-7). "Another distinguishing character of agricultural growth in the 1980s has been its wider dispersal over regions" with the "fact the foodgrains outgrowth picked up in many less developed areas" (Sawant and Achuthan 1995, A-13). Since the mid-1970s in India, there has been a "significant" decline in "inter-state disparities in real wages" caused by labor migration from poorer ares, the "decline in the relative prices of foodgrains," poverty alleviation programs and the "pick-up in agricultural growth" in poorer areas (Hanumantha Rao 1994, 43). In addition, gender disparities have diminished as female wages have been rising as "traditional semi-feudal relations in agriculture" have been weakened under the impact of the improved agricultural technology (Hanumantha Rao 1994, 43, 51, 55-58, 60-63). The Green Revolution driven global decline in the relative price of foodgrains has been a major force for poverty reduction, particularly in Asia, for the obvious reason that the poor spend a much higher portion of their income on foodgrains than other income groups. Hanumantha Rao vividly describes the "miserable" working conditions for migrant labor in India, their exploitation by employers and middlemen and their declining income share in "areas undergoing rapid technological change." However, "despite the hardships and exploitation, the incomes of the migrant labour are higher than they would have been able to earn without migration" (Hanumantha Rao 1994, 52 & 54). In the "process of migration, the labour has become more skillful, enterprising, and has considerably improved its staying power on account of rise in its income. This has enhanced its capacity to fight against injustices"

(Hanumantha Rao 1994, 55).

It is important to note that "among initial conditions conducive to pro-poor growth, literacy plays a notably positive role" (Datt and Ravallion 1999). Datt and Ravallion found that "the same variables that promoted growth in average consumption also helped reduce poverty" (Datt and Ravallion 1996). The higher agricultural yields of the Green Revolution were pro poor in that they "reduced absolute poverty in rural India, both by raising smallholder productivity and by increasing real agricultural wages." These benefits were not "confined to those near the poverty line -- the poorest also benefited" (Ravallion and Datt 1995). Thanks to the efficiacy of these agricultural technology, economic growth did not have to be sacrificed in order for there to be benefits for the poor. In fact, "there was no sign of tradeoffs between growth and pro-poor distribution" (Datt and Ravallion 1996). On the debate on whether there has been rising inequality as a result of globalization, Martin Ravallion is often seen as one who supports the view of increasing inequality. However, he also finds "from the point if view of the poor," income distribution "has not been deteriorating in the 1990s" (Ravallion 2001, 1807).

One hates to imagine all the famine, disease and death that would have resulted if these spectacular yield increases had not happened or the destruction of wildlife habitat from desperately hungry people trying to grow food for themselves and their family (Hanumantha Rao 1994, 161-163, 189). "Some estimates of land savings due to all past research efforts and agricultural intensification amount to more than 400 million ha. Mineral fertilizers may have provided 30-50% of these savings and have therefore made a major contribution to the preservation of tropical rainforests and biodiversity" (Norse 2003, see also Pinstrup-Andersen, 2003).

It is generally recognized by demographers that regularized and improved food supply is one of a constellation of development outcomes which lead to low infant death rates which in time lead to the lower fertility rates. For about thirty years after World War II, death rates fell faster than birth rates - the population growth rate is the difference between the two, birth rates minus death rates - causing population growth rates reaching about 2.3% per year by the early 1970s. Since the mid-1970s, birth rates have been falling faster than death rates, slowing population growth which will likely lead to a leveling of population at about 9 billion by the mid twenty-first century and possibly even initiate a long term decline. Whatever environmental problems (as well as those of poverty and hunger) that we face today, they will be greatly compounded unless modern agronomy is able to continue to facilitate sustainable increases in yields using the technologies that are increasingly being opposed in the name of protecting the environment.

The Green Revolution technology in rice involved HYVs (high yielding varieties) of rice with a significantly shorter growing season allowing the farmer to plant more than one crop per year increasing output both by higher yields and more crops. The seeds generally came as part of a package of along with fertilizer and pesticides and often with access to water. Plants like living organisms of all kinds need nutrients to grow. Higher yields required more nutrient input no matter what the crop is. In effect, the Green Revolution turned tens or even hundreds of millions of peasant subsistence agriculturalists into mini agribusinesses buying inputs and selling outputs to pay for inputs and to secure a small profit. There were environmental cost from more intensive, sometimes year-round planting and population growth. For example, in an island like Java with 120 million people in an area the size of the state of Wisconsin, soil erosion and pesticide contamination of the groundwater were and are problems. IPM (Integrated Pest Management) programs using a variety of strategies for pest control including the use of predator insects such as spiders to help to control the insects that eat the crops have helped to reduce pesticide use in many areas but the task is often difficult and not always successful. Disease resistant varieties of rice have probably been more effective in protecting the crop than IPM but a multiplicity of strategies for crop protection has merit. An IPM program for cabbage in central Java was teaching farmers to "scout" for bugs, count them and only spray when they reached a certain density instead of once a week. When I asked a farmer not in the program and spraying by the calendar what he would say if I told him that a farmer across the valley was spraying less than half the number of times that he was and getting the same output, he responded that he wouldn't believe me. The very success of the Green Revolution package of technologies has made it difficult to make even minor adjustments that benefit the environment. The speed at which "tradition" bound small farmers adopted the HYVs in paddy literally everywhere it could be grown, surprised even the most optimistic among us. The farmer having experienced the lower yields and more frequent crop loss of traditional agriculture was not easily convinced to even slightly modify the technology package that had so dramatically transformed the local food supply and decreased hunger and malnutrition. Those of us who have witnessed this transition in Asia and through time, have little doubt about the overall accuracy of the statistics which show an absolute and proportional decrease in hunger and malnutrition and increase in height that is readily observable throughout most of Asia (for example, see Morgan 2000 for China).

Central to the anti-modern agronomy mythology is the belief that the Green Revolution technologies have led to a vast increase in mono cropping, worsened the nutritional quality of the human diet and fostered a mentality which has been pejoratively called "monocultures of the mind" (Shiva 1993). If Shiva thought about what she was saying and checked the data on health in India, she might have trouble explaining the following data cited by Nanda:

Annual Life expectancy went from 44 years in 1960 to 61.6 years in 1995. Infant mortality rate declined from 165 to 73 per 1000 births from 1960 to 1995. Percentage of underweight children declined from 71 in 1960 to 53 in 1995. Adult literacy went up from 34 percent in 1960 to 52 percent in 1995 (Nanda 2003, 272 citing UNDP 1998).

One activist, Alex Wijeratna of ActionAid, generalizes the nutritional attack against the Green Revolution by claiming that: "Two billion people now have diets less diverse than 30 years ago. The Green Revolution stripped out the micro nutrients and encouraged monocropping" (Wrong 2000). Rice has had an association with monoculture long before the Green Revolution. It might therefore come as surprise to many that "rice harvested area (hectares under rice multiplied by the number of croppings per year) has declined as a percentage of total crop harvested area in nearly all Asian rice-growing economies since 1970" (Dawe 2003, 33). For example, rice in China went from a 0.24 share of total crop area harvested in 1970 to 0.18 in 2001 while Vietnam went from a 0.75 to a 0.62 share in 2001 in the same period in becoming the second largest rice exporter in the world to Thailand which went from 0.64 share to 0.57 share. "Thus, if some farmers increasingly specialized in rice, others must have diversified into other crops -- and done so over a larger harvested area. Despite a near doubling of the total rice harvest, rice is now less dominant in Asian agriculture than it was before the Green Revolution" (Dawe 2003, 33). Stated differently, "overall cropping diversity -- the variety of different crops planted -- also seems to have increased since the beginning of the Green Revolution ... farmers in most Asian countries plant a wider variety of different crops today than was the case in 1970" (Dawe 2003, 33). Contrary to popular misconceptions and consistent with our analysis above, Dawe finds that these increases in production have resulted in a decline in child malnutrition. "While the incidence of child malnutrition still stood at a dismal 31% in 1995, this reflected a reduction of one-third from the 46.5% recorded in 1970" (Dawe 2003, 33, see also Smith and Haddad 2001).

A variety of new agricultural technologies and techniques, both high and low tech, hold significant promise to make agriculture more sustainable and environmentally friendly. Some are more likely to be associated with agribusiness but they need not be. No tillage agriculture where farmers use a drill for planting or lightly disc the field and then use herbicides to protect the crop, has several advantages. By maintaining ground cover, soil moisture is preserved and soil erosion is prevented and greater biodiversity is preserved from year-to-year. The "organic" agriculture alternative to using herbicides is to deep plough the field to turn the weeds under so they cannot regenerate and/or to hand weed with low paid migrant labor once the crop is growing (Lee 2003, Henshaw 2003, Fulmer 2003 and Roane 2002). Added to the widely practiced no tillage agriculture, is what is now called precision agriculture which combines the best in a variety of techniques. Using GPS (global positioning systems) and other technologies on their combine, farmers can measure the precise output from each and every area of the farm so that they can more precisely regulate the next year's planning so as not to use too much or too little of any inputs including fertilizer and chemical pesticides. Contrary to some critics, no farmer, corporate or individual, wishes to destroy the land in which they have invested nor do they wish to waste money using excess amounts of inputs of any kind. A high tech form of IPM using computers with expert systems software and access to online data sources and a variety of technologies for taking temperature, humidity and other measures including soil moisture, farmers can monitor their fields ("scouting") for insects etc. and plug in the data into their expert system program to learn whether they should apply a pesticide and more important, whether they should refrain from doing so. The result is greater output obtained with fewer chemical inputs and less disruption of the soil.

We have a variety of technologies to make all forms of agriculture more environmentally sustainable if we have the right incentives to promote them and can continue the research necessary to increase output without bringing large amounts of new land under cultivation. The task of development economists is to find lower cost affordable ways of adapting these technologies to allow the poorer farmers of the world to both feed their families and preserve their environment.

CONCLUSION

The Green Revolution is a validation of the basic ideas of Evolutionary or Institutional economics. Or at least this is the case for the Institutional economics that I learned from David Hamilton at the University of New Mexico in the 1950s and Clarence Ayres and others in the 1960s at University of Texas. Economic Development was seen as being research and knowledge driven and the most important capital was what was found between your ears. The Green Revolution was and remains a research revolution. Certainly, the Institutionalist tradition had a vastly more positive view of what could be achieved than was the case for mainstream economists who were thinking in terms of scarcity, capital formation and very low rates of economic growth. The economic transformation of many regions of Asia may seem like a "miracle" to some but to someone in the Texas tradition, it comes more as a pleasant surprise that is understandable in terms of a theory of technological change.

John Dewey's Instrumental philosophy of problem solving had built into it the idea that all solutions carry with them, their own set of problems. Progress was understood not in terms of problem-free solutions but whether the problems created were of lesser magnitude than those that were solved. Whatever the problems of the Green Revolution may be, they pale in comparison with the mass famine, disease and death that would have arisen without it. Often when describing the yield increases of the Green Revolution, economists refers to them as being "land augmenting" which is interesting because mainstream economics has always referred to land as being a "fixed factor of production." Erich Zimmermann's functional theory of resources would simply view land as being part of the raw stuff of the Universe that is transformed by human ingenuity (Zimmermann 1951). It is not arable land that created agriculture but agriculture that created arable land and technological change through time has enhanced its resource character. Technology creates resources and resource creation in agriculture is land augmenting.

The Instrumental/Institutionalist tradition was and supposedly remains a radical tradition that focused concern on meeting the needs of those at the lower end of the economic totem pole. Initially, the Green Revolution seemed to disproportionately benefit the better-off farmers who had the capacity to utilize the new technology. Since the mid-to-late 1970s, it is clear that the very poorest - poor urban consumers and subsistence farmers have become the primary beneficiaries. As with all change, there has been continuing institutional resistance against the Green Revolution, though some of the quarters from which this opposition has emerged are surprising.

The Instrumental/Institutionalist theory viewed technological and economic change as an ongoing process. Problem solving creates problems which in turn need to be addressed as well as new problems which emerge because of other factors such as population growth. The Green Revolution is far from over but there is never-the-less some evidence of slowing of its advances with the evident need for what has been called a "double Green Revolution" of biotechnology if we are to accommodate both the expected three billion increase in population by mid-century as well as the increase demand for improved diet with more vegetable, dairy, egg and meat products. Unfortunately, the misinformation about the Green Revolution, often described as a "failure," is being used as an argument against the use of biotechnology in agriculture though not in pharmaceuticals.

The argument against biotechnology is often couched in anti-corporate rhetoric. Those making this argument do not understand the Veblenian distinction between business and industry or between a technology and the social structure controlling it. Ironically, the combination of misinformation about the impact of the Green Revolution and total opposition to the agricultural biotechnology including acts of wanton vandalism, makes it more difficult to promote public funding of the biotechnology research that could be made available to poor farmers. Whatever the mix of causal forces, there has been a decline in funding for the network of international agricultural research centers (IARCS) that were the driving force for the Green Revolution.

Opposition to biotechnology has been led by European and North American based groups most of whom have no experience in agriculture or any history of helping the poor. Many view modern science (often pejoratively referred to as logophalocentric and reductionist) as the enemy which raises the issue for some amongst us who might be enamored of this position as to what extent can or should a dissenting tradition in economics which focused on the central importance of scientific and technological change draw from dissenting streams in science (or more accurately anti-science) particularly when these systems of thought stand in opposition to what is considered to be modern science?

One argument is made that we do not need the new technology because there is enough food for everyone if it were fairly distributed. One wonders where this "enough food for everyone" came from if the Green Revolution was such a failure. Moreover, nobody can reasonably claim that there is enough food to feed the expected 9 billion people by mid-century. To this Institutionalist, the argument seems rather strange that one cannot simultaneously engage in technological change and reforms that make its benefits more widely distributed. It sounds much like the mainstream economists arguments that there was a trade-off between growth and equity. In fact, for the first decades of development economics, there was the ongoing discussion about how much growth needed to be sacrificed in order to get more equity and how best to do this. As noted above, the greater the equity, the more effective was the Green Revolution in increasing output and reducing poverty. This is in many ways a vindication of Institutional thought that long argued that equity facilitated growth and was not counterproductive to it.

I can personally recall many discussions over the past decades about trying to find some niche in the growing season or some other way to squeeze in an oilseed crop or some other crop to diversify the poor farmers' diet. Increasing yields has made that increasingly possible but not always. When poor farmers obtain 70% or more of their calories from one crop, rice, there is a definite need to improve the nutritional content of that crop. Key to any discussion was the recognized need that in any technological package to deliver both yield and nutritional improvement, the seed was central. Many of these discussions took place long before the possibility of biotechnology were recognized so it can not be said that this recognition is merely an excuse conjured to support corporate producers of bioengineered seeds. To put it starkly, at the core of any agronomic process, is it best for farmers to continue using the seeds that have fed them but at less than adequate levels of nutrition? Or do we move forward with a process of delivering to the farmer seeds which embody the latest and best in modern science and technology? My training as an Institutional economist and my experience as a development economist makes me opt for the latter.

As someone who has worked with farmers in many areas, believe me those that I encountered have been actively seeking ways of bettering their lot in life and that of their family. Improved seeds has always been high on the agenda of what they felt was necessary for them to continue on a pathway of improvement. SAVING THE SEED may have a virtuous ring to it for those in affluent countries that have never experienced the hard scrabble of poor farmers trying to feed a family on the meager crop from tiny plots planted with low yielding, disease infested saved seeds. Let the affluent retain their romantic assumptions while letting the poor farmers have access to the technology that can better their lot in life.

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***Maize or corn follow the usage of authors cited. Otherwise, it is corn for the United States and maize for the rest of the world.

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