Socio-Cultural Aspects of Native Maize Diversity

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for the Secretariat of the Commission
for Environmental Cooperation of North America

As part of the Article 13 initative on
Maize and Biodiversity: the Effects of Transgenic Maize in Mexico

1. State of knowledge

In Latin America alone, more than two and a half million hectares are under traditional agriculture, in the form of raised fields, polycultures and agroforestry systems, documenting the successful adaptation of a set of farming practices to difficult environments (Altieri 1991). Many of these traditional agroecosystems, still found throughout the Andes, Meso America and the lowland tropics, constitute major *in situ* repositories of both crop and wild plant germplasm. These plant resources are directly dependent upon management by human groups; thus, they have evolved in part under the influence of farming practices shaped by particular cultures and the forms of sophisticated knowledge they represent. It is no coincidence that countries containing the highest diversity of plant forms also contain the greatest number of ethnic groups.

The existence of such genetic diversity, particularly in centers of origin, has special significance for the maintenance and enhancement of productivity of agricultural crops in developing countries characterized by variable agro-climates and heterogeneous environments. Such diversity provides security to farmers against diseases, pests, droughts and other stresses and also allows them to exploit the full range of agroecosystems existing in each region but differing in soil quality, altitude, slope, water availability, etc. A wide variety of plant species represents an important resource for subsistence farming communities, as they form the foundation sustaining current production systems and biological systems essential for the livelihoods of local communities (Clawson 1985). Folk crop varieties, also known as land races or traditional varieties, are also valued by farmers because of the cultural values with which they are imbued, such as their symbolism in religious ceremonies or their use as gifts in weddings or rewards in community work projects. At the same time, such land races are extremely important for industrial agriculture because they contain a vast amount of genetic diversity, including traits needed to adapt to evolving pests, and changing climates and soils, as well as for sustainable forms of agriculture that maintain yields while reducing the external inputs that usually cause environmental degradation. These traditional varieties have been generally viewed by Western societies and organizations as part of the common heritage of humankind (Cleveland and Murray 1997).

It is important to note that the sources of greatest varietal diversity tend to be the poor, isolated, and often-marginal areas in the developing world, and the farmers who usually conserve the most diverse traditional crop germplasm are likely to be the poorest. Although estimates of the number and location of resource-poor farmers vary considerably, it is estimated that about 1.9–2.2 billion people remain directly or indirectly untouched by modern agricultural technology (Pretty 1995). Despite the increasing industrialization of agriculture, the great majority of farmers are peasants or small producers, who still farm the valleys and slopes of the rural landscapes (mostly semi-arid and hillsides that are ecologically vulnerable) with traditional and subsistence methods. Their agricultural systems are small-scale, complex and diverse and exhibit somewhat stable yields with a minimum of external inputs (Beets 1982). In Latin America, peasant production units reached about 16 million in the late 1980s occupying close to 60.5 million hectares, or 34.5 percent of the total cultivated land (De Grandi 1996). The peasant population includes 75 million people, representing almost two-thirds of the

Latin America's total rural population (Ortega 1986). Average farm size of these units is about 1.8 hectares, although the contribution of peasant agriculture to the general food supply in the region is significant. In the 1980s, it reached approximately 41 percent of the agricultural output for domestic consumption, and is responsible for producing at the regional level 51 percent of the maize, 77 percent of the beans, and 61 percent of the potatoes.

2. Areas of disagreement

There are three areas of socio-cultural disagreements including the linkages between poverty and genetic diversity, how much do indigenous peasants know?

Poverty and genetic diversity

The association of genetic diversity with traditional agriculture has been perceived in development and scientific circles as negative, and thus linked to underdevelopment, low production and poverty. Many people involved in international agriculture view on-farm conservation of native crop diversity as opposite to agricultural development (Brush 2000). Many proponents of the Green Revolution assumed that progress and achieving development in traditional agroecosystems would inevitably require the replacement of local crop varieties with improved ones, and that the economic and technological integration of traditional farming systems into the global system would be a positive step enabling increased production, income and, commonly, well-being (Tripp 1996; Wilkes and Wilkes 1972). But, according to many authors critical of top-down agricultural development, the integration evinced by the Green Revolution instead brought about several negative impacts (Wilkes and Wilkes 1972):

a) The Green Revolution involved the promotion of a package that included modern varieties (MVs), fertilizer and irrigation, marginalizing a great number of resource-poor farmers who could not afford the technology.

b) In areas where farmers adopted the package, stimulated by government extension and credit programs, the spread of MVs greatly increased the use of pesticides, often with serious health and environmental consequences.

c) Increased uniformity caused by sowing large areas to a few MVs increased risk for farmers. Genetically uniform crops proved more susceptible to pests and diseases, and also improved varieties did not perform well in marginal environments where the poor live.

d) Diversity is an important nutritional resource of poor communities, but the spread of MVs was accompanied by a simplification of traditional agroecosystems and a trend toward monoculture, which affected dietary diversity, thus raising considerable nutritional concerns.

e) The replacement of folk varieties also represents a loss of cultural diversity, as many varieties are integral to religious or community ceremonies. Given this, several authors have argued that the conservation and management of agrobiodiversity may not be possible without the preservation of cultural diversity.

f) The perception of folk varieties as “raw material” to be freely used for the breeding of modern crop varieties, and now transgenic varieties, directly collides with indigenous notions of intellectual property rights, leading to conflicts with indigenous communities who claim rights of control over their own folk varieties against those of industrial-world plant breeders or corporations (Cleveland and Murray 1997). This is a relevant consideration in the context of Mexico and the Andean region, where important indigenous movements have a very different view of the value and proper use of genetic resources. In fact, in a recent statement, one of the most powerful unions of Mexican peasant farmers (UNOSJO) strongly manifested their dissatisfaction with the contamination of local varieties by transgenic crops in the Sierra Juárez de Oaxaca (Gonzalez 2002).

How much do indigenous peasants know?

As mentioned earlier, traditional agroecosystems are the result of a complex coevolutionary process between natural and social systems, which has resulted in ingenious strategies of ecosystem appropriation. In most cases, the indigenous knowledge behind the modification of the physical environment is very detailed. Ethnobotanies and folk taxonomies are perhaps the most complex of all forms of indigenous knowledge (Brokenshaw *et al.* 1980). The ethnobotanical knowledge of certain campesinos in Mexico is so elaborate that the Tzeltal, P'urepecha, and Yucatan Mayans can recognize more than 1200, 900 and 500 plant species, respectively (Toledo *et al.* 1985).

Despite the evidence, many scientists still perceive traditional knowledge as the product of ignorance or something outmoded, and understanding how traditional farmers maintain, preserve, and manage biodiversity remains a major research challenge. Many agronomists, other scientists, and development consultants have been unable to recognize the fact that crop genetic resources are more than just a collection of alleles and genotypes of native crops and wild relatives, but also include ecological interactions, such as gene flow via cross-pollination among crop populations and species, and human selection and management, guided by systems of knowledge and practice associated with genetic diversity, especially complex folk taxonomies and the adaptation to heterogeneous environments. Today it is still not widely accepted that indigenous knowledge is a powerful resource in its own right and is complementary to knowledge available from Western scientific sources. Unfortunately, due to this, more often than not, many scientists have ignored traditional farmers' rationales and imposed conditions and technologies that have disrupted the integrity of native agriculture. This was prophetically stated by Berkeley geographer Carl Sauer after visiting Mexico at the invitation of the Rockefeller Foundation in the wake of the Green Revolution:

> A good aggressive bunch of American agronomists and plant breeders could ruin native resources for good and all by pushing their American commercial stocks….And Mexican agriculture cannot be pointed toward standardization on a few commercial types without upsetting native economy and culture hopelessly. The example of Iowa is about the most

> dangerous of all for Mexico. Unless the Americans understand that, they'd better keep out of this country entirely. This must be approached from an appreciation of native economies as being basically sound.

<u>Potential impacts of transgenic crops on traditional agroecosystems</u>

Concerns have been raised about whether the introduction of transgenic crops may replicate or further aggravate the effects of MVs on the genetic diversity of land races and wild relatives in areas of crop origin and diversification and, therefore, affect the cultural thread of communities. The debate was prompted by a controversial article in *Nature* reporting the presence of introgressed transgenic DNA constructs in native maize land races grown in remote mountains in Oaxaca, Mexico (Quist and Chapela 2001). Although there is a high probability that the introduction of transgenic crops will further accelerate the loss of genetic diversity and of indigenous knowledge and culture, through mechanisms similar to those of the Green revolution, there are some fundamental differences in the magnitude of the impacts. The Green Revolution increased the rate at which modern varieties replaced folk varieties, without necessarily changing the genetic integrity of local varieties. Genetic erosion involves a loss of local varieties but it can be slowed and even reversed through *in situ* conservation efforts that conserve not only land races and wild-weedy relatives, but also agroecological and cultural relationships of crop evolution and management in specific localities. Examples of successful *in situ* conservation have been widely documented (Brush 2000).

The problem with introductions of transgenic crops into regions of genetic diversity is that the spread of characteristics of genetically altered grain to local varieties favored by small farmers could dilute the natural sustainability of these races (Nigh *et al.* 2000). Although many proponents of biotechnology believe that unwanted gene flow from GM-maize may not compromise maize biodiversity (and therefore the associated systems of agricultural knowledge and practice, along with the ecological and evolutionary processes involved) and may pose a threat no worse than cross-pollination from conventional (non-GM) seed. In fact, some industry researchers believe that DNA from engineered maize is unlikely to have an evolutionary advantage, but that if transgenes do persist they may actually prove advantageous to Mexican farmers and crop diversity. But here a key question arises: Can genetically engineered plants actually increase crop production and, at the same time repel pests, resist herbicides, and confer adaptation to stressful factors commonly faced by small farmers? Thermodynamic considerations suggest that they cannot: traits important to indigenous farmers (resistance to drought, suitable quality for food or fodder, competitive ability, performance on intercrops, compatibility with household labor conditions, and more advantageous maturity, storage quality, taste or cooking properties, etc.) could be traded for transgenic qualities that may not be important to farmers. Under this scenario, risk will increase and farmers will lose their ability to adapt to changing biophysical environments and produce relatively stable yields with a minimum of external inputs while supporting their communities' food security.

Most scientists agree that teosintes and maize interbreed. One problematic result from a transgenic maize-teosinte cross would come about if the crop-wild relative hybrids achieved an evolutionary advantage by acquiring greater tolerance to pests (Ellstrand 2001). Such hybrids could become problem weeds, upsetting farmers' management but also out-competing wild relatives. Another potential problem derived from transgenic crop-to-wild gene flow is that it could lead to extinction of wild plants via swamping and out-breeding depression (Stabinsky and Sarna 2001).

But the impacts of transgenic contamination of land races may not be limited to introgression-mediated changes in crop or wild relative fitness. Introduction of transgenic crops could also affect the biological balance of insect communities within traditional agroecosystems. In the case of *Bt*-maize, it is known that natural enemies of insect pests could be directly affected through inter–trophic-level effects of the *Bt* toxin. The potential of *Bt* toxins to move through insect food chains poses serious implications for natural biocontrol in agricultural fields. Recent evidence shows that the *Bt* toxin can affect beneficial insect predators that feed on insect pests present on *Bt*-crops (Hilbeck 1998). Studies in Switzerland show that mean total mortality of predaceous lacewing larvae (*Chrysopidae*) raised on *Bt*-fed prey was 62 percent compared to 37 percent when raised on *Bt*-free prey. These *Bt*–prey-fed Chrysopidae also exhibited prolonged development time throughout their immature life stage (Hilbeck 1998). This and other studies have divided the entomological community, as not all agree on the severity and significance of the findings (Obricki *et al.* 2001, and debate appearing in subsequent *Bioscience* issues).

To some, these findings can be of concern to small farmers who rely on the rich complex of predators and parasites associated with their mixed cropping systems for insect pest control (Altieri 1994). Inter–trophic-level effects of the *Bt* toxin raise serious concerns about the potential for disruption of natural pest control. Polyphagous predators that move throughout the crop season within and between mixed crop cultivars subjected to transgenic pollution will surely encounter *Bt*-containing non-target prey (Hilbeck 1999). Disrupted biocontrol mechanisms may result in increased crop losses due to pests or to increased use of pesticide by farmers, with potential consequent health and environmental hazards.

But the environmental effects are not limited to crops and insects. *Bt* toxins can be incorporated into the soil though leaf materials when farmers plow under transgenic crop residues after harvest. Toxins may persist for two to three months, resisting degradation by binding to clay and humic acid soil particles while maintaining toxin activity (Palm *et al.* 1996). Such active *Bt* toxins that end up and accumulate in the soil and water from transgenic leaf litter may have negative impacts on soil and aquatic invertebrates and nutrient cycling processes (Donnegan and Seidler 1999).

The fact that *Bt* retains its insecticidal properties and is protected against microbial degradation by being bound to soil particles, persisting in various soils for at least 234 days, is of serious concern for poor farmers who cannot purchase expensive chemical fertilizers. These farmers instead rely on local residues, organic matter, and soil microorganisms for soil fertility (key invertebrate, fungal, or bacterial species), which can be negatively affected by the soil-bound toxin (Saxena *et al.* 1999). By losing such ecological services, poor farmers will become dependent on fertilizers with serious economic implications.

3. Priority Topics for a Pro-Peasant Research Agenda

Creating safeguards against homogenization

In today's globalized world, technological modernization of small farms through monocultures, new varieties, and agrochemicals is perceived as a critical prerequisite for increasing yields, labor efficiency and farm incomes. As conversion from subsistence to cash agricultural economy occurs, the loss of biodiversity in many rural societies is progressing at an alarming rate. As peasants directly link to the market economy, economic forces increasingly influence the mode of production characterized by genetically uniform crops and mechanized and/or agrochemical packages. As adoption of modern varieties occurs, land races and wild relatives are progressively abandoned (Altieri *et al.* l987).

The above situation is expected to be aggravated by the technological evolution of agriculture based on emerging biotechnologies, whose development and commercialization is increasingly concentrated and under the control of a few corporations, accompanied by the increased withdrawal of the public sector as major provider of research and extension services to rural communities (Jordan 2001). The social impacts of local crop shortfalls, resulting from genetic uniformity or changes in the genetic integrity of local varieties due to genetic pollution, can be considerable in the margins of the developing world. In the extreme periphery, crop losses mean ongoing ecological degradation, poverty, hunger and even famine. It is under these conditions of systemic market failures and the lack of public external assistance that local skills and resources, associated with biological and cultural diversity, should be available to rural populations to maintain or recover their production processes.

Diverse agricultural systems and genetic materials that confer high levels of tolerance to changing socio-economic and environmental conditions are extremely valuable to poor farmers, as diverse systems buffer against natural or human-induced variations in production conditions (Altieri 1995). Impoverished rural populations must maintain low-risk agroecosystems that are primarily structured to ensure local food security. Farmers in the margins must continue to produce food for their local communities in the absence of modern inputs, and this can be reach by preserving *in situ* ecologically intact locally adapted agrobiodiversity. For this, it will be necessary to maintain pools of genetic diverse material, geographically isolated from any possibility of cross fertilization or genetic pollution from uniform transgenic crops. These islands of traditional germplasm within specific agroecological landscapes will act as extant safeguards against the potential ecological failure derived from the second green revolution imposed in the margins.

In situ conservation and rural development in GMO-free centers of origin

Given the destructive trends described above, many scientists and development workers have emphasized the need for *in situ* conservation of local crop genetic resources and the environments in which they occur (e.g., Prescott-Allen and Prescott-Allen 1981). However, most researchers consider that *in situ* preservation of land races would require a return to or the preservation of microcosms of primitive agricultural systems, an unacceptable and impracticable proposition (Frankel and Soul 1981). It is here contended, nevertheless, that maintenance of traditional agroecosystems is the only sensible strategy to preserve *in situ* repositories of crop germplasm. Any attempt at *in situ* crop genetic conservation must struggle to preserve the agroecosystem in which these resources occur. In the same vein, preservation of traditional agroecosystems cannot be achieved isolated from maintenance of the socio-cultural organization of the local people (Altieri and Merrick 1987). Ultimately, if biodiversity conservation is indeed to succeed among small farmers, the process must be linked to rural development efforts that give equal importance to local resource conservation, food self-sufficiency and some level of market participation.

Preservation efforts should be linked to an overall rural development agenda that focuses on conservation opportunities rather than exclusively on possibilities to enhance production. In this case, the primary aim of traditional agriculture shifts to one which focuses on productive forms of conservation targeting those populations most at risk from poverty and food insecurity and, that are least able to benefit from agricultural modernization, but rather may suffer the unintentional consequences of intensification such as genetic pollution. The idea is to design sustainable farming systems and appropriate technologies aimed at upgrading peasant food production for self-sufficiency by incorporating native crops and wild/weedy relatives within and around fields of production to complement the various production processes (Altieri and Merrick 1987, Brush 2000).

While in the eyes of development specialists, marginal rural communities represent failure in economic development, to agroecologists they represent success in relation to conservation of diversity. It is precisely this ability to generate and maintain diverse crop genetic resources that offers “unique” niche possibilities to marginal farmers that can not be replicated with uniform and highly productive systems in the more favorable lands. As globalization leads to greater homogeneity between and within societies, the “difference” that remains within marginal environments (i.e., land races free from transgenic contamination) comprises one of the greatest resources of poor farmers. Such a “difference” can be strategically utilized by exploiting unlimited opportunities that exist for linking traditional agrobiodiversity with local markets, but also with tourist and international markets, as long as these activities are carefully planned in participatory modes and remain under grassroots control.

Basing a rural development strategy on traditional farming and ethnobotanical knowledge not only assures continual use and maintenance of valuable genetic resources but also allows for the diversification of peasant subsistence strategies, including links with external markets (Alcorn 1984, Caballero and Mapes 1985). But in order for peasants to have a truly competitive edge, they will need to be able to produce “unique” agricultural crops (i.e., GMO-free) for niche markets. Such “uniqueness” is also crucial for the maintenance of the stability of their local farming systems in times of uncertainty.

CITATIONS and REFERENCES

Alcorn, J. B. 1984. *Huastec Mayan Ethnobotany.* Austin: University of Texas Press.

Altieri, M. A. 1995. *Agroecology: The Science of Sustainable Agriculture*. Boulder: Westview Press.

Altieri, M.A. 1994. *Biodiversity and Pest Management in Agroecosystems*. New York: Harworth Press.

Altieri, M. A., M.K. Anderson, and L.C. Merrick. 1987. Peasant agriculture and the conservation of crop and wild plant resources. *J. Soc. Conservation Biology*. 1: 49–58.

Altieri, M.A. and L. C. Merrick. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany* 4: 86–96.

Beets, W.C. 1982. *Multiple Cropping and Tropical Farming Systems*. Boulder: Westview Press.

Berlin, B, D.E. Breedlove and P.H. Raven. 1973. General principles of classification and nomenclature in folk biology. *American Anthropologist* 75: 214–242.

Brokenshaw, D.W., D.M. Warren and O. Werner. 1980. *Indigenous Knowledge Systems and Development.* Lanham: University Press of America.

Brush, S.B. 1982. The natural and human environment of the central Andes. *Mountain Research and Development* 2: 14–38.

Brush, S.B. 1986. Genetic diversity and conservation in traditional farming systems. *J. Ethnobiol.* 6: 151–167.

Brush, S.B. 2000. *Genes in the Field: On-farm Conservation of Crop Diversity*. Boca Raton, Fl: Lewis Publishers.

Bye, R.A. 1981. Quelites—ethnoecology of edible greens—past, present and future. *J. Ethnobiol.* 1: 109–123.

Caballero, J.N., and C. Mapes. 1985. Gathering and subsistence patterns among the P'urhepecha indians of Mexico. *J. Ethnobiol.* 5: 31–47.

Chacon, J.C. and S.R. Gliessman. 1982. Use of the "non-weed" concept in traditional agroecosystems of south-eastern Mexico. *Agro-Ecosystem* 8: 1–11.

Chang, J.H. 1977. Tropical agriculture: crop diversity and crop yields. *Econ. Geogr.* 53: 241–254.

Cleveland, D.A. and S.C. Murray. 1997. The world's crop genetic resources and the riphts of indigenous farmers. *Current Anthropology* 38: 477–492.

Clawson, D.L. 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. *Econ. Bot.* 39: 56–67.

De Grandi, J.C. 1996. El desarrollo de los sistemas de agricultura campesina en America Latina. Serie FAO-*Gestion de Sistemas de Explotacion Agricola* #12. Rome: FAO. P83. Division, Santiago.

Denevan, W.M., J.M. Treace, J.B. Alcorn, C. Padoch, J. Denslow and S.T. Paitan. 1984. Indigenous agroforestry in the Peruvian Amazon: Bora Indian management of swidden fallows. *Interciencia* 9: 346–357.

Donnegan, K.K. and R. Seidler. 1999. 'Effects of transgenic plants on soil and plant micro-organisms'. Recent Research Developments. *Microbiology* 3: 415–24.

Ellstrand, N.C. 2001. When transgenes wander, should we worry? *Plant Physiology* 125: 1543–1545.

Fowler, C. and P. Mooney. 1990. *Shattering: Food, Politics and the Loss of Genetic Diversity.* Tucson:University of Arizona Press.

Gliessman, S.A., E. Garcia and A. Amador. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agro-ecosystems. *Agro-Ecosystems* 7: 173–185.

Gonzalez, A.R. 2002 Contaminacion de maizes natives por trangenicos en la Sierra Juarez de Oaxaca, Mexico. UNOSJO, S.C. <www.rafi.org>.

Grigg, D.B. 1974. *The Agricultural Systems of the World: An Evolutionary Approach.* Cambridge: Cambridge University Press.

Harlan, J.R. 1976. The possible role of weed races in the evolution of cultivated plants. *Euphytica* 14: 173–176.

Hilbeck, A., W.J. Moar, M. Putzai-carey, A. Filippini, & F. Bigler (1999). 'Prey-mediated effects of Cry1Ab toxin and protoxin on the predator *Chrysoperla carnea'*. *Entomology, Experimental and Applied* 91: 305–16.

Jordan, C.F. 2001. Genetic engineering, the farm crisis and world hunger. *BioScience* 52: 523–529.

Louette, D. 2000. Traditional management of seed and genetic diversity: what is a landrace?. In: *Genes in the Field.* S. Brush (ed). Lewis Publishers, Florida. pp. 109–142.

Nabhan, G.P. 1983. *Papago Indian Fields: Arid Lands Ethnobotany and Agricultural Ecology.* Unpubl. Ph.D diss., University of Arizona, Tucson.

Nigh, R, C. Benbrook, S. Brush, L. Garcia-Barrios and R. Ortega-Packa 2000. Transgenic crops: a cautionary tale. *Science* 287: 1927.

Obrycki, J.J., J.E. Losey, O.R. Taylor and L.C.H. Jessie. 2001. Transgenic insecticidal maize: beyond insecticidal toxicity to ecological complexity. *BioScience* 51: 353–361.

Ortega, E. 1986. Peasant agriculture in Latin America. Joint ECLAC-FAO Agriculture

Palm, C.J., D.L. Schaller, K.K. Donegan and R.J. Seidler. 1996. Persistence in soil of transgenic plant produced *Bacillus thuringiensis* var. *Kustaki* -endotoxin. *Canadian Journal of Microbiology* 42: 1258–62.

Prescott-Allen, R. and C. Prescott-Allen. 1981. In-situ conservation of crop genetic resources: A report to the International Board for Plant Genetic Resources. Rome: IBPGR.

Pretty, J. 1995. *Regenerating Agriculture*. Washington, DC: World Resources Institute.

Quist, D. and I.H. Chapela. 2001. Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. *Nature* 414: 541–543.

Richards, P. 1985. *Indigenous Agricultural Revolution*. Boulder: Westview Press.

Rissler, J. and M. Mellon. 1996. *The Ecological Risks of Engineered Crops*. Cambridge: MIT Press.

Robinson, R.A. 1996. *Return to Resistance: Breeding Crops to Reduce Pesticide Resistance.* Davis: AgAccess.

Saxena, D., S. Flores and G. Stotzky. 1999. Insecticidal toxin in root exudates from *Bt* corn. *Nature* 40: 480.

Stabinski, D. And N. Sarno. 2001. Mexico, centre of diversity for maize, has been contaminated. *LEISA Magazine* 17: 25–26.

Toledo, V.M. 1980. La ecología del modo campesino de producion. *Antropología y Marxismo* 3: 35–55.

Toledo, V.M., J. Carabias, C. Mapes, and C. Toledo. 1985. *Ecología y Autosuficiencia Alimentaria*. Mexico City: Siglo Vientiumo Editors.

Tripp, R. 1996. Biodiversity and modern crop varieties: sharpening the debate. *Agriculture and Human Values* 13: 48–62

Wilken, G.C. 1970. The ecology of gathering in a Mexican farming region. Econ. Bot. 24: 206-245.

Wilken, G.C. 1977. Integrating forest and small-scale farm systems in middle America. *Agro-Ecosystems* 3: 291–302.

Wilkes, H.G. and K.K. Wilkes. 1972. The green revolution. *Environment* 14: 32–39.