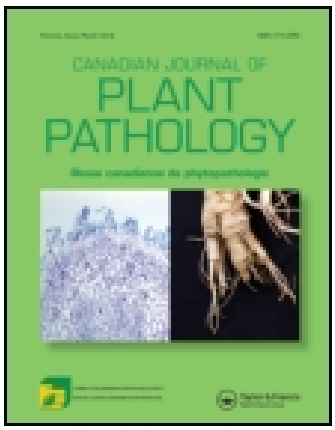

Canadian Journal of Plant Pathology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tcjp20

Sustainable agriculture: future hope for developing countries

Y.L. Nene [a]
[a] ICRISAT Center , Patancheru, Andhra Pradesh, 502 324, India
Published online: 29 Dec 2009.

To cite this article: Y.L. Nene (1996) Sustainable agriculture: future hope for developing countries, Canadian Journal of Plant Pathology, 18:2, 133-140, DOI: 10.1080/07060669609500637

To link to this article: http://dx.doi.org/10.1080/07060669609500637

CANADIAN JOURNAL OF PLANT PATHOLOGY 18:133–140, 1996

Sustainable agriculture: future hope for developing countries

Y.L. Nene

Deputy Director General, ICRISAT Center, Patancheru, Andhra Pradesh 502 324, India.

The R. Glenn Anderson Lecture, sponsored jointly by the Canadian Phytopathological Society and the American Phytopathological Society, was established to recognize the contributions made by R. Glenn Anderson to the security of the world's food supply. The second of these lectures was presented by Dr. Y.L. Nene during the plenary session devoted to sustainable agriculture at the 6th International Congress of Plant Pathology held at Montreal, 28 July–6 August 1993.

Aided by a political resolve, the dedication of their scientists, and strong international support, many developing countries made remarkable progress in achieving self-sufficiency in food and natural fiber during the last two decades. However, increasing population and commercialization of agriculture in these countries have put enormous pressure on the resources needed for a sustained growth in agricultural production. Limited arable lands are being overexploited reducing their productivity. Erosion-prone marginal lands are being brought under cultivation. Faulty irrigation practices, coupled with poor drainage, have made many areas less productive than before. Several time-tested stable cropping systems have been given up in favor of new, unstable systems to obtain higher yields per unit area. Indiscriminate use of fertilizers and pesticides has led to serious unforeseen problems adversely affecting the stability of crops. In spite of these setbacks, there is hope of achieving sustainable growth in agricultural production. This can be done by improving land and water management practices; discovering stable, high-productivity farming systems including crops and livestock; evolving better, environment-friendly crop health management practices; using new biotechnology tools; supporting international agricultural research centers sponsored by the Consultative Group for International Agricultural Research; involving nongovernmental organizations and government agencies in efforts to educate and support farmers; and most important of all, implementing innovative programs to reduce population growth rates with the total commitment of the concerned governments.

Nene, Y.L. 1996. Sustainable agriculture: future hope for developing countries. Can. J. Plant Pathol. 18:133–140.

Pour la troisième fois depuis la Seconde guerre mondiale, nous craignons les conséquences d'un épuisement des ressources naturelles, et nous nous soucions de la transformation de l'environnement. En outre, au tournant du XX^{e} siècle, nous arrivons au terme de l'une des plus remarquables périodes de transition de l'histoire de l'agriculture : le passage d'un monde agraire dépendant des ressources naturelles à des modèles d'exploitation scientifiques. Mais un examen prospectif nous enseigne que les sources possibles d'accroissement de la production agricole ne sont pas aussi facilement discernables qu'il y a vingt-cinq ans. Dans cet article, l'auteur décrit sommairement une série d'importantes contraintes biologiques et techniques, liées aux ressources et à l'environnement et liées à la santé humaine, qui exercent leurs effets sur l'accroissement de la production agricole.

Food production has substantially increased in many developing countries in recent decades mainly because of a political resolve by these countries to improve their lot. Remunerative prices, dedication of farm scientists, perseverance by farmers, and strong international support — all helped a great deal in this effort. For example, Mexico increased its wheat production fourfold between 1950 and 1984. Indonesia doubled its rice production during the same period. India tripled its wheat production between 1967 and 1987. China increased its grain output by about 50% between 1976 and 1984 (York 1990).

With the partial shift from subsistence farming to commercial farming, where making profits rather than making a living became the sole objective, the efforts to increase food production have inadvertently led to imprudent use of natural resources. These efforts included use of erosion-prone marginal lands, drastic land levelling resulting in the loss of rich topsoil, excessive application of water, over-exploiting ground-water resources, monocropping instead of intercropping and regular fallowing, indiscriminate use of pesticides, heavy application of concentrated chemical fertilizers, and deforestation to bring more land under crops. Stable farming systems were disrupted. Crop production and animal production were separated for the sake of more profitable ventures. In spite of the spectacular increases in food production in the recent past, nagging doubts continue about having sufficient food in the years to come. Growing concern about the global environment has made the whole community of agricultural scientists much more conscious about the limits of the natural resource base than ever before. Today we are faced with a challenge to meet mankind's basic need for food in the centuries to come, without damaging the environment.

Several definitions of sustainable agriculture are available. No definition is perfect, but the one adopted by the Technical Advisory Committee (TAC) of the Consultative Group for International Agricultural Research (CGIAR) seems satisfactory. It reads:

> "Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources" (TAC 1989).

The contents of my lecture relate to this definition.

Present scenario

Population and additional food requirement. The current world population is more than 5.0 billion. It is projected to be 6.3 billion in 2000, 8.3 billion in 2020, and about 10 to 12 billion in 2050. Over 3 billion people, or about 60% of the world population, live in Asia. Africa harbors over 0.6 billion and Latin America over 0.4 billion people (IRRI 1990). Though the annual rate of population growth is higher in Africa (about 3%) than in Asia (about 1.8%) or Latin America (about 1.8%), the sheer vastness of the population in Asia at present and the projected population by the middle of the next century point to a far more serious situation in Asia than in Africa and Latin America. Since 70% of the potentially arable land is already under cultivation, bringing new land under cultivation to increase food production in Asia is not possible, unless forests are cut and additional marginal lands are brought under cultivation — a choice that could lead to environmental disasters and reduce the chances of long-term sustainability. Africa and Latin America are better placed. Africa presently uses only 25% of the arable land and Latin America only 15% (Strong 1989). About 25% of the projected increase in global crop demand over the next four decades could possibly be met by bringing additional land under crop production. This means that the remaining 75% of the projected increase in demand must come from increased yield per unit area (Crosson & Anderson 1992). Even though food production has increased 3- to 4-fold since 1950 in 116 developing countries, only about 40 countries have been able to keep pace with the population growth of the 1980s. Food crop yields must be increased by at least 40% over the next 20 years to merely maintain the current level of food availability (Per Pinstrup-Andersen 1993). A challenging task indeed!

Soil degradation. A significant threat to sustainable agriculture lies in soil degradation. Soil erosion, deterioration of soil structure, loss of nutrients, build-up of salts and toxicants, waterlogging, and desertification alone or in combination are contributing to soil degradation in most developing countries. According to the Food and Agriculture Organization of the United Nations (FAO), the global loss of productive crop land due to soil degradation is estimated at 6 to 7 million ha each year, of which more than 1 million ha are abandoned due to poor irrigation practices (TAC 1989).

In western Africa most soils are highly degraded and low in fertility. Organic matter is generally very low and soils are deficient in natural nitrogen, phosphorus, and sulphur. Acidity and aluminium toxicity, soil crusting, compaction, and sealing during and following rains are common. Soil crusting and rain storms cause high run-off and low infiltration (Day et al. 1990). According to a United Nations Environment Programme report, some 90% of the productive dry and rangelands in Sudano-Sahelian Africa and 70% of the productive dryland in southern Asia have suffered in productivity due to land degradation (UNEP/ISRC 1990). More than 40% of Ethiopia's area and 88% of its farmers are in the highlands. Land degradation is a major issue in that country and it is estimated that 60 000 ha of arable land are lost each year (ICRAF 1993). Similarly an estimated 79% of total land area of Mexico has erosion problems (Altieri & Masera 1993).

In India about 60% of the cultivated area suffers from soil erosion, waterlogging, and salinity problems. About 30 million ha of fragile land now under cultivation is progressively degrading (Dudani & Carr-Harris 1992). Faulty cultivation practices such as unnecessary deep ploughing, disturbing soil topography, excessive weeding, excessive irrigation, and inadequate use of organic manure — all contribute to soil degradation.

Increasing deforestation is a cause of great concern. Deforestation adversely affects water storage capacity of catchment areas, stream flow, agricultural productivity, and availability of fuel, and influences the local as well as the global climate. Deforestation increases soil erosion and results in the loss of biodiversity (Harmsen & Kelley 1993). There is, however, a viewpoint that soil lost due to erosion should not be considered as a total loss since that soil might aid productivity elsewhere (Crosson & Anderson 1992).

The water resource. Water resource availability varies considerably among the developing countries and from one region to another within those countries. Some countries have made considerable progress towards increasing capacity for irrigation whereas others still have to do a good deal more. In several countries where irrigation potential has been increased, the irrigation water-use efficiency is low. Let me take India as an example.

In the pre-independence period (prior to 1947), irrigation was developed to stabilize agriculture, and not solely to increase agricultural productivity. After independence, the irrigated area has risen from 19.5 million ha to about 68 million ha of which 40% is from the ground water and the rest from surface irrigation (Kanwar 1988). At present more than 30% of the arable area of the country is under irrigation and another 20% can be brought under irrigation. Even with the present capacity India can produce more food than at present, but that is not happening. An integrated soil-water management technology has not been adopted. Large dams were constructed over several rivers after independence to generate electricity as well as to irrigate land through a canal system.

This water is excessively used in some parts of the country. Consequently little water is left for farmers towards the lower ends of canals. Crops that do not fit in with the agroclimate of certain regions are grown merely because water is available leading to its highly inefficient use (e.g. wheat in tropical areas). Drainage of water from irrigated areas is a problem as it raises the water-table and increases soil salinity. Flood irrigation, which is probably the most inefficient method, is followed by many farmers. Tank irrigation systems in southern India and in Sri Lanka have been practised since ancient times. Many tanks have now silted partially or completely. In many areas, ground water is being over-exploited through tube wells, far more than ever before and in excess of ground water recharge.

Land use systems. There has been a substantial change in land use systems followed by farmers in different countries. New cropping systems, adopted because of the market demand, have replaced the old, stable systems without much thought to sustainability. In the Indian state of Punjab, for example, increased irrigation facilities motivated farmers to grow a sole wheat crop instead of the time-tested traditional wheat/chickpea (garbanzo) intercrop. Then when the sole chickpea crop was raised in the submontane Punjab and adjoining regions in nonirrigable areas, the formation of its own canopy, which was never the case with intercropped chickpea, provided a favorable environment for the development of botrytis gray mold. Increased irrigation, botrytis gray mold, and periodic epidemics of ascochyta blight have pushed this crop to areas outside Punjab and its adjoining states.

In irrigated areas of northwestern India and Pakistan, the wheat-rice rotation, which is a completely new system, has become most common. It is well-known now that this cropping system is becoming a constraint to obtaining higher yields from either of the two crops. In the Chiang Mai Valley of northern Thailand, with high inputs, rice (paddy) yields at first increased from 4 t/ha to 7 t/ha. After 10 years, however, yields reverted to traditional levels in spite of continued high inputs of lime and fertilizers (TAC 1989). Some of the new land use systems have disregarded the time-tested, highly effective system of crop rotation as well as the practice of green manuring. Because of the high demand for cereals, production of legumes in rotation has received less attention. It will not be out of place to mention the combined role of cereals and legumes in providing balanced nutrition to people who cannot afford to eat meat or who do not eat meat by choice.

Purchased inputs. In a desperate bid to rapidly increase food production, farmers in many developing countries were trained and encouraged to follow intensive, high-input agriculture. However, we find that fertilizers have been used without due consideration of the individual nutrient requirement of the plant. Application of organic manures has been deemphasized in most countries. Faulty fertilizer applications have resulted in wastages and in pollution of the ground water. With liberal application of macronutrients, micronutrient deficiencies, not unexpectedly, have become more evident. With excessive biomass of crops per unit area as a result of heavy fertilizer applications, diseases and pests have been more serious in several situations and that required applications of fungicides and insecticides. Excessive use of insecticides has caused worldwide concern. For example a few years ago, in the state of Andhra Pradesh in southern India, 56% of the total pesticide application was concentrated in 5% of the area under cotton (Sankaram 1991). Insecticide resistances have often been encountered in the target pests. Heavy machinery has been used even on fragile soils, further contributing to soil degradation. Costs of inputs have soared in the past few years and therefore the net economic returns to farmers are often less than before, causing disappointment and discontent among farmers.

If the developing countries wish to attain long-term self-sufficiency or self-reliance in food production, these counter-productive situations need to be tackled. There are no standard prescriptions for ensuring sustainability of agriculture across all developing countries. Each country will have to chalk out its own course. I must clarify that many of the suggestions that I am going to discuss will require considerable field research before they can be implemented.

What should be the future scenario?

Maintaining quality of the land resource. Land degradation can be minimized to a very large extent and productivity of these soils can be restored. The first step should be to increase the organic matter content of the soils through incorporation of as much crop stubble as possible, addition of various kinds of composts, inclusion of rotation crops that contribute organic matter through dropped leaves, and use of legumes as green manure. Biogas plants in rural communities have been encouraged in many countries to provide fuel for cooking. The organic residue from these biogas plants is an excellent source of organic matter for soils. Biodegradable urban wastes need to be composted systematically and provided to farmers. Governments could even consider providing assistance in transporting organic manures from cities to rural areas, where farmers often do not have adequate quantities of manures. Last year I saw a very interesting program on a British TV channel about turning human wastes into manure in a socially acceptable way. People in some of the developing countries will

have to shed their old prejudices and use every kind of organic matter, especially city wastes, to improve and maintain soil productivity.

Shallow ploughing is common in South Asia and this is what should be continued unless specific situations require deep ploughing. In the Indian subcontinent, summer fallow of 2 to 3 months, in which soil is ploughed lightly and left exposed to the summer heat, has been practised for many centuries. This should be continued, as far as possible, even though in irrigated areas there is a tendency to grow a summer crop. Solarization of soils should be very useful provided low-cost, biodegradable plastics become available. Minimum tillage, wherever possible, is most desirable.

Forest area should be increased, particularly in areas where soils are poor. No new deforestation should be allowed, except in a planned way. Wherever possible, mulching should be encouraged to reduce soil erosion. Planting of grasses such as vetiver on sloping bunds/lands reduces erosion, and therefore should be encouraged. Wind erosion in the Sahel region of West Africa can be reduced considerably by planting parallel hedges as wind breaks and by mulching the soil. Leguminous hedgerows planted along the land contours significantly reduce soil erosion.

Sustainability of agriculture in acidic or saline soils can be improved by adding organic matter and by growing acid- or salt-tolerant plant species/cultivars. Salt-tolerant Kallar grass, *Leptochloa fusca* (L.) Kunth., used in Pakistan for reclaiming saline soils, and acid-tolerant rice cultivars developed by the Centro Internacional de Agricultura Tropical (CIAT) are good examples. Contour bunding has been practised for many decades but needs to be made more efficient. Raised beds and furrows system of land configuration for planting crops has been used in Ethiopia for many centuries and the system could be further improved. For the vertisol regions where rainfall is relatively more assured, graded, raised broadbeds and furrows (slope 0.4–0.8%) are very efficient. Each raised bed helps in moisture conservation and reduces erosion. The shallow furrow provides good surface drainage (Ryan et al. 1982). As for alfisols, which are common in developing countries, better technologies of soil management than those available at present need to be developed.

Means to reclaim eroded soils will have to be devised and implemented. For example, special efforts have been conceived for semi-arid soils of Iraq that have been eroded to the C horizon (Smith & Elliott 1990). These include soil loosening with deep phosphorus and sulfur placement, direct-drilling, return of crop residues, and inclusion of a legume in crop rotation practices.

Prudent water management. Water is a key resource for increasing food production. I had pointed out that water needs to be more efficiently used than at present. The distribution of canal water has to be improved to cover additional areas. Desilting of old tanks and canals needs to be undertaken. Small water reservoirs should be preferred to large ones. The watershed concept needs to be followed seriously for groups of villages. The real hope for nonirrigated areas is through efficient rain-water management. This can be done by i) increasing the capacity of soils to absorb water, ii) occupying land with crop as fully as possible during the rainy seasons, iii) harvesting the excess water from fields to a community water reservoir (watershed concept) and using that water to give life-saving irrigations, iv) avoiding use of community water reservoirs for growing crops with high water requirement (e.g. paddy, sugarcane), and v) growing drought-tolerant crop cultivars. Ground water use must be legislated to prevent overuse. Projects to improve drainage of irrigation water are absolutely essential to maintain productivity of irrigated lands for future generations. Appropriate pricing of water to show that it is a valuable resource should improve water-use efficiency. As management of water resources by government agencies has rarely been efficient, privatization of major irrigation facilities is worth exploring.

Conserving crop diversity. There is a consensus on conserving crop diversity in the interest of sustainability of agriculture. In subsistence farming, farmers have been growing local landraces and many different crops, a practice that assured preservation of crop diversity. However, with the advent of commercial agriculture and consequent arrival of elite, high-yielding genotypes, crop cultivar diversity was threatened. Today many international centers of the CGIAR are holding germplasm in trust for the world community and making it freely available to anyone who can make use of it. In addition, many gene banks exist both in developed and developing countries. The CGIAR Centers' share currently is only 16% of the world germplasm collections. About 45% of the collection is held by countries in Europe and North America. Other countries, mostly in Asia, Africa, and Latin America, hold the remaining 39% (Anonymous 1993). Germplasm utilization will have to be increased and genetic vulnerability will have to be avoided through planned diversification of crop cultivars. The present conflict of interest between Plant Breeders' Rights and Farmers' Rights will have to be settled amicably.

Stable farming systems. Even though a shift from subsistence to commercial farming is evident in most developing countries, a large number of small farmers, for various reasons, are still following their traditional farming systems, particularly in the rainfed areas. In fact 60% of the world's arable land is under

traditional farming systems (CGIAR 1992). However, in irrigated areas of commercial farms, one can see continuous cropping, year after year, without any break. Most people agree that a break, such as a summer break in the tropics and subtropics, is good for sustainable agriculture.

Crop rotations, based on widely known principles, must be re-emphasized. Research on new crop rotations will be useful. Rotations should continue to include nitrogen-fixing legumes, crops having different water requirements, short-duration crops and cultivars, and crops that would lead to reduction of soilborne pathogens and insect pests affecting them. Relay cropping and intercropping need to be encouraged. For example, rice farmers in northern Vietnam are following a new technology of sprouting early maturing maize in their paddy dikes 10 to 15 days before rice harvest in September. The maize seedlings are then transplanted into wet rice fields immediately after the rice is harvested. About 140 000 ha in Vietnam are under this system, yielding 3.2 t/ha of maize (CIMMYT 1990).

In West Asia and North Africa, chickpea is normally planted in spring. Two CGIAR Centers, the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), have evolved a new cropping system that allows farmers to obtain twice the normal yields of chickpea. This involves planting of chickpea with resistance to ascochyta blight in the beginning of winter, instead of spring, thereby giving more time for chickpea to produce additional biomass and grain yield. Turkey has recorded a significant increase in chickpea production mainly due to fallow replacement in cereal-fallow rotation. This is likely to increase further with adoption of winter chickpea (Sakar & Yilmaz 1990).

Agroclimatological studies will help identify the most optimal cropping systems. ICRISAT's work has shown that in the Sahel region of western Africa, the date of onset of rain varies up to one month, but the date of cessation of rain is much more predictable. Thus one can predict the approximate length of the growing season after the rain begins and decide upon which crops or crop varieties should be grown so as to make the optimal use of rain water (Sivakumar 1992).

Crop diversification will be most desirable. According to an estimate 10 000 to 80 000 plant species are edible and man has used at least 3000 species in his diet at various times. Today only 29 species account for 90% of our food products (Sasson 1990). There is certainly scope to evaluate new crop species for food and fiber.

I wish to mention one rather unique crop species, pigeonpea [*Cajanus cajan* (L.) Millsp.], which is widely grown at present in the Indian subcontinent, and commonly grown in eastern Africa and central America, and which is a mandate crop of ICRISAT. Pigeonpea's contribution to sustainability has already been evident. It is a perennial woody shrub that is normally grown as an annual. Pigeonpea is called a "biological plough" because it can send its roots deep into hard layers of soil. It is very drought tolerant. Its root system secretes piscidic acid that solubilizes nonavailable phosphorus so that it partly meets its own phosphorus requirement. It can add up to 40 kg/ha of nitrogen to the cropping system through biologically fixed nitrogen. It smothers weeds once it is established. It drops a large mass of old leaves and thus contributes organic matter to the soil. New cultivars and hybrids of short duration that mature in 90–100 days compared to 200–270 days of traditional cultivars, and those that are almost photoperiod-insensitive, can fit into many new cropping systems between latitudes of 45°N and 45°S. Long-duration types can be used as an agroforestry species, not only to provide food, fodder, and fuel, but also to prevent soil erosion. Pigeonpea's green whole seed is used as a vegetable and the protein-rich, dry split pea to make a thick soup that is consumed with cooked rice. Its crushed seed is used as animal feed, and dry sticks as fuel or for making huts, baskets, etc. The crop is also used for culturing a scale insect that produces lac, a kind of sealing wax. There are not many crop species like pigeonpea with so many positive features. We must use such species more than before and extend their cultivation to nontraditional areas.

For stability of farming systems, particularly on small farms, practising animal husbandry is most desirable. In fact small farmers in most developing countries keep cattle, pigs, goats, sheep, and poultry, to supplement their incomes. This system needs to be encouraged, supported, and made more profitable. The work of CIAT on a rice-pasture system developed for the acidic savannas in Latin America is very relevant and praiseworthy.

Judicious use of purchased inputs. The use of chemical fertilizers and pesticides will have to continue, as it is not easy to revert to the old system of no inputs. These inputs are necessary to get high sustainable yields, but they need to be used judiciously. A combination of organic manures and fertilizers should ensure increased yields as well as long-term sustainability.

New integrated crop health management systems will become necessary. These should be based on i) stable and durable host resistance to both biotic and abiotic stress factors, ii) biological control, iii) useful cultural practices particularly those which the old-world farmers have followed for centuries, e.g. the slash/mulch system called *frijol tapado* (covered

beans) of controlling web blight [*Thanatephorus cucumeris* (Frank) Donk] of beans in Costa Rica (Thurston 1992), and iv) the use of pesticides only when it is absolutely essential.

It is easy for me to make a statement about judicious use of inputs, but in practice it is a very difficult and challenging task for research and extension workers to get the message across to farmers, particularly the commercial farmers in developing countries.

Modern biotechnology too has a role. There is every reason to believe that modern biotechnology will contribute to sustainable agriculture. It is expected to help in the i) production of microorganisms beneficial to crop agriculture, ii) rapid propagation of useful plant species and microorganisms, iii) new powerful diagnostics based on the use of monoclonal antibodies and nucleic acid probes for the diagnosis of plant diseases and the detection of toxic residues, iv) genetic engineering of plant species to incorporate new traits, v) new genetic mapping techniques for plant breeding programs based on the use of restriction fragment length polymorphisms (RFLPs) as an aid to conventional plant breeding, vi) production of new vaccines and diagnostics for animal health programs, and vii) use of embryo technology, especially for cattle (Persley 1990). Some developing countries have embarked upon systematic biotechnology research programs, but many others are unable to do so. International cooperation will be necessary for transfer of technologies to developing countries. In the foreseeable future biotechnology will support conventional plant and animal breeding procedures and not replace them.

International agricultural research. One of the most remarkable innovations in international agriculture has been the establishment of the CGIAR in 1971 under the umbrella of FAO, United Nations Development Program (UNDP), and the World Bank. The founders saw a catalytic role for international agricultural research centers (IARCs) in strengthening the food security of developing countries. The 18 IARCs, the majority of which are located in developing countries, get funding and technical support from both developed and developing countries. My institute, ICRISAT, collaborates in research with 42 institutions in 17 developed countries and with national research systems in more than 30 developing countries. These IARCs function with least interference from any quarter and have played a key role in increasing production of major cereals, legumes, and root crops in developing countries. I have no doubts that the IARCs are needed to support sustainability efforts in developing countries.

If one looks at some of the specific research and development recommendations of the United Nations Conference on the Environment and Development (UNCED) 1992, as contained in Agenda 21, one would appreciate how close these are to the goals of the CGIAR, particularly those relating to poverty alleviation, linkages between increased agricultural productivity and environmental protection, and role of scientific research (Ryan 1992). Sustainability of agriculture is influencing all the research agendas of the IARCs. So far the largest donor countries have been the USA, Japan, and Canada, followed closely by several European countries. The largest institutional donors have been the World Bank, Inter-American Development Bank, the European Economic Community (EEC), and the UNDP. The Rockefeller and Ford Foundations, which have an outstanding track record of assistance to developing countries, are also donors. Thus it is evident that the developed countries have provided the bulk of the financial support to the CGIAR so far and the time has now come for at least some of the developing countries, particularly those which have been major beneficiaries of the CGIAR system, to increase their financial contributions to the CGIAR.

Developed countries will have to continue to help many developing countries in the foreseeable future to move towards a sustainable agriculture. In 1988, the Decima research firm in Toronto contacted 1000 Canadians to get their opinions on international aid policies. Eighty-five percent of the respondents believed that the best kind of help is support for scientific research in developing countries (IDRC 1990). Surely there cannot be a better way of supporting agricultural research in developing countries than by generously supporting the CGIAR system, which already has well-established research linkages with developing countries and which serves as a bridge between research institutions of developed and developing countries.

Government support to farmers. Over the past two decades, governments of many developing countries have become more aware of the importance of agriculture than before. Concerned governments, and increasingly nongovernment organizations (NGOs), have paid attention to problems related to agriculture. However, much more needs to be done. During my travels in developing countries, I have often read statements in local newspapers describing the high morale of the defence forces of those countries. However, I have never read a statement that would indicate existence of a high morale of the farmers in those countries. Defence is usually looked after by one ministry or department. However, more than one ministry or department deals with farmers' concerns, and consequently the focus on farmers has not frequently been sharp. I have often wondered if at least some developing country governments could establish a single ministry or department of farmers'

affairs to sharpen the focus on all economic and social problems of farmers and thus raise and sustain the morale of farmers of their countries.

Reduced population growth — the key to food security. I have covered several possible actions that would contribute to sustainable agriculture in developing countries. The most important action, however, would be planning for small families to ensure reduced population growth rates. Food security through sustained agricultural development will be possible only if present rates of population growth are drastically reduced. Increasing literacy, especially among women, and better health care will contribute substantially towards population reduction. Public awareness, especially in rural areas, will have to be increased and here NGOs could play a major role. Incentives for small families will have to be introduced. Public hygiene and change in food habits are other areas that need attention. For example, the present food habits of the people of India require high amounts of edible oils and fats, and India had to import over US$ 2 billion worth of edible oils between 1981 and 1986 (Ministry of Agriculture, India 1989). This bill would have been far less if food habits were more nutrition-oriented than taste-oriented. Also, it is disturbing to note that 5% of the richest Indians use about 40% of all available edible oils and fats, whereas the poorest 20% use less than 5% (P.V. Shenoi, ICRISAT, personal communication).

Whether we like it or not, food habits will have to change. Foods which are efficiently produced will have to dominate the diets of both the rich and the poor. Wastage of food, which is unbelievably large, will have to be reduced. It would be appropriate if the mass media were to project the thoughts and experiences of Masanobu Fukuoka, Mahatma Gandhi, Henry David Thoreau, and others on simple living so as to curb lavishness in food consumption. Mahatma Gandhi once said "Earth provides enough food to satisfy every man's need, but not for every man's greed."

It just took two days in 1970 for a fungal parasite *Paecilomyces farinosus* (Dick. ex Fr.) Brown & Smith, to wipe out a cotton whitefly (*Bemisia tabaci* Genn.) culture, that I had maintained for two years and, that consisted of thousands of whitefly adults crowded in a cage. Many in the audience would be aware of such happenings in nature. This is nature's way of controlling populations. Political leaders, religious leaders, social workers, and the lay population must realize that if they do not ensure a reduction in population, nature will ensure it; and nature's ways of reducing populations are cruel and merciless.

Concluding remarks

Sustained growth in agricultural production is basic to human survival. Working together, farmers, farm scientists, bureaucrats, and politicians of developing countries can ensure a sustainable agriculture. I know the Canadian and American phytopathological societies are "sustainable" and therefore I am sure the Glenn Anderson lectureship will continue. Fifty years from now, if the person who delivers this lecture is able to describe a stable food situation in the world, souls of people like Glenn Anderson will rest in peace.

Assistance received from C. Johansen, J.G. Ryan, Ma, Cynthia Bantilan, S.M. Virmani, P.V. Shenoi, Jugu Abraham, V.K. Sheila, G.J. Michael, and Sue D. Hall in the preparation of this manuscript is gratefully acknowledged.

Altieri, M.A., and **O. Masera.** 1993. Sustainable rural development in Latin America: building from the bottom-up. Ecological Economics 7:93–121.

Anonymous. 1993. A decade in review. Seedling 10(1). Special 10th Anniversary Issue. p. 6.

CGIAR. 1992. CGIAR Fact Sheet 10. *In* CGIAR Fact Sheets. Biodiversity and plant genetic resources. CGIAR, Washington, DC, USA.

CIMMYT. 1990. CIMMYT 1989 Annual Report. Beyond Subsistence: New Options for Asian farmers. CIMMYT, Mexico. p. 30.

Crosson, P., and **J.R. Anderson.** 1992. Global food resources and prospects for the major cereals. World Development Report 1992. Background Paper 19. World Bank, Washington, DC, USA.

Day, J.C., W.R. Butcher, and **D.W. Hughes.** 1990. An economic analysis of farm management practices and improved technologies in the Sahel. Pages 311–332 *in* R.P. Singh, J.F. Parr, and B.A. Stewart, eds., Advances in Soil Science. Volume 13. Dryland Agriculture: Strategies for Sustainability. Springer-Verlag, New York, USA.

Dudani, A.T., and **J. Carr-Harris.** 1992. Agriculture and people. South-South Solidarity, New Delhi, India. 45 pp.

Harmsen, K., and **T. Kelley.** 1993. Natural resource management research for sustainable production. Resource Management Program, ICRISAT, Patancheru, India. p. 29.

ICRAF. 1993. Integrated natural resource management research for the highlands of East and Central Africa. Report of the Consultative Workshop held 6–8 January 1993, Entebbe, Uganda. ICRAF, Nairobi, Kenya. p. 32.

IDRC. 1990. The global research agenda. A south-north perspective. IDRC, Ottawa, Canada. p. 40.

IRRI. 1990. IRRI Rice Facts. IRRI, Manila, Philippines.

Kanwar, J.S. 1988. Keynote address: Water management the key to developing agriculture. Pages 55–71 *in* J.S. Kanwar, ed., National Seminar on Water Management The Key to Developing Agriculture. Agricole Publishing Academy, New Delhi, India.

Ministry of Agriculture, India. 1989. Technology Mission on Oilseeds. Towards Self-reliance. Progress Report 1986–89. Ministry of Agriculture, New Delhi, India.

Per Pinstrup-Andersen. 1993. Commentary: Ending world hunger requires a new vision and renewed investment in agricultural research and development. IFPRI Report 15(1):1 and 6.

Persley, G.J. 1990. Beyond Mendel's Garden: Biotechnology in the Service of World Agriculture. C.A.B. International, Wallingford, Oxon, UK. 155 pp.

Ryan, J.G. 1992. Agricultural productivity and sustainability in the semi-arid tropics: Is there such a thing as a free environmental lunch? ICRISAT, Patancheru, India. 18 pp.

Ryan, J.G., S.M. Virmani, and **L.D. Swindale.** 1982. Potential technologies for deep black soils in relatively dependable rainfall regions of India. Pages 41–61 *in* Proceedings of the Seminar on Innovative Technologies for Integrated Rural Development, 15–17 April 1982, Indian Bank, New Delhi, India.

Sakar, D., and **B. Yilmaz,.** 1990. Effect of advancing sowing dates on chickpea production in Turkey. Pages 289–290 *in* Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4–8 Dec 1989, ICRISAT Center, India. ICRISAT, Patancheru, India.

Sankaram, A. 1991. Sustainability of Indian agriculture: options opportunities challenges. Tamil Nadu Agricultural University, Coimbatore, India. 29 pp.

Sasson, A. 1990. Feeding Tomorrow's World. Sextant 3. UNESCO, Paris, France. p.607.

Sivakumar, M.V.K. 1992. Empirical analysis of dry spells for agricultural applications in West Africa. J. Climate 5.:532–539.

Smith, J.L., and **L.F. Elliott.** 1990. Tillage and residue management effects on soil organic matter dynamics in semiarid regions. Pages 69–88 *in* R.P. Singh, J.F. Parr, and B.A. Stewart, eds., Advances in Soil Science. Volume 13. Dryland Agriculture: Strategies for Sustainability. Springer-Verlag, New York, USA.

Strong, M.F. 1989. Ending hunger through sustainable development. The Hunger Project, New York, USA. 30 pp.

TAC. 1989. Sustainable agricultural production: implications for international agricultural research. FAO Research and Technology Paper 4. FAO, Rome, Italy. 131 pp.

Thurston, H.D. 1992. Sustainable Practices for Plant Disease Management in Traditional Farming Systems. Westview Press, Boulder, Colorado, USA. pp. 86–98.

UNEP/ISRC. 1990. World map on status of human-induced soil degradation. United Nations Environment Programme, Nairobi, Kenya.

York Jr., E.T. 1990. Sustainable agricultural production. International Agriculture Newsletter 147:1–2.

Yeshwant L. Nene

Yeshwant L. Nene is Deputy Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), in Patancheru, India. He received his Ph.D. from the University of Illinois in 1960 and was instrumental in developing a university plant pathology program in research, teaching and extension in Pantnagar, India. He joined ICRISAT in 1974 and became leader of the pulses improvement program and later program director for legumes. In 1989 he became Deputy Director General and presently coordinates the institute's global research programs for the improvement of sorghum, pearl millet, peanut, pigeonpea, and chickpea. He also works on resource management and genetic preservation.