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Reorientation of Agricultural Higher Education: Research and Extension Systems for the 21st Century

T.K. Gill[1]* and S.S. Gill[2]

[1] Associate Professor, Department of Extension Education,
Punjab Agricultural University, Ludhiana 141004 India
[2] Ex-Director of Extension Education, Directorate of Extension Education
Punjab Agricultural University, Ludhiana 141004 India

We suggest the reorientation of agricultural higher education in light of some emerging issues in the context of globalization, such as food security, diversification, sustainability of ecosystems, and agribusiness. These issues will pose challenges to future agricultural scientists, particularly in the developing countries. The curriculum of agricultural higher education needs to be made more broad based by including topics such as biotechnology, genetic engineering, agro-meteorology, environmental science, agro-ecology, computer application, information technology, conservation of natural and human resources, specialized job-oriented courses, and trade and export in agribusiness in the context of globalization. Manpower has to be trained scientifically to develop technologies in various areas. Finally, adequate emphasis should be placed on practical skills and entrepreneurial capabilities among the students to achieve excellence.

Key words: Agricultural Education, Research, Extension, Food Security, Sustainability

The Present Situation of Agriculture

The world as a whole has been making progress towards improved food security and nutrition, but this progress has been slow and uneven. Indeed many countries and population groups have failed to make significant progress, and some have even suffered setbacks in their already fragile food-security and nutrition situations. Presently 858 million people are affected by hunger. Most of them are from developing countries, especially Asian and African countries. By 2025, 8.5 billion people, 83% of the expected world population, will be living in these developing countries (Kumar and Singh, 2003). The gigantic task of feeding the millions can only be achieved by increasing productivity from existing land, improving the nutritional quality of farm produce to deal with the problem of malnutrition without disturbing ecosystem stability, and preserving the resources for future generations. The following are some of the emerging issues that will pose challenges to future agricultural scientists, particularly in developing countries, and require the reorientation of the agricultural higher education system to produce scientific manpower capable of meeting these challenges: ensuring food security, promoting diversification, sustaining ecosystems, promoting agro-processing and agri-business in the context of globalization, and revamping the extension system.

Food Security

Food security is the basis of all achievements made by man. World food production grew at the rate of 3.0% per annum in the 1960s, 2.3% per annum in the 1970s, and 2.0% per annum between 1980 and 1992 (Alexandratos, 1995). Kindle (2002) reported that the world's farmers must pro-

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* Corresponding author: Associate Professor, Department of Extension Education, Punjab Agricultural University, Ludhiana 141004 India.
Tel: +91-98145-87551, E-mail: tkbahga1@rediffmail.com

duce 40% more rice, wheat, and other grains in order to achieve food security. Due to low productivity and low prices, farmers are moving away from growing coarse cereals and prefer to grow more cash crops for economic benefits (Rao, 1997). This factor has also affected nutritional security because coarse cereals have more nutritive value to remedy the protein, caloric, and mineral malnutrition. The average per capita annual food consumption of pulses is also falling in developing countries: it is 7.5 kg today, compared with 12 kg in the early 1960s. Similarly per capita consumption of vegetable oils in developing countries is around 8 kg per annum as compared to 16 kg in 1960 (Alexandratos, 1995). Further, the world's largest corn exporter, the United States, has converted one-third of its crops to biofuel production due to the overconsumption of oil stocks, further reducing the world's food supply (Egarr, 2008).

To ensure food security and nutritional security, productivity can be increased by adopting strategies such as increasing yield; increasing the area under crop cultivation; preventing losses due to insects, pests, and diseases; preventing post-harvest losses; and promoting biotechnology.

Increasing Yield

Though crop yields have increased greatly through the adoption of high-yielding varieties, high inputs and better technologies, a wide gap still exists between productivity and the actual potential in many areas. For example, the average irrigated rice yield in developing countries is 3.7 ton per hectare, but some countries achieve only 1.0 ton and others 10.0 ton. An assessment of prospects for irrigated rice indicated that the average irrigated rice yield of all countries could be 5.2 ton per hectare in 2010 (Alexandratos, 1995). In Asia the experimental yield for irrigated rice and wheat areas has reached a plateau and has been virtually static for the past 10 years (Pingali *et al.,* 1990). Average farm yields in these areas are still well below experimental yields. Maximization of production by increasing cropping intensity would have negative effects on the environment. Genetically engineered crops and other biotechnological innovations may be feasible options to increase yield and are discussed in greater detail below.

Increasing the Area Under Crop Cultivation

Increasing crop yield will not be possible beyond certain limits, so the area under crop cultivation should also be increased. Land currently used in crop production in the developing countries (excluding China) amounts to some 760 million ha, of which 120 million ha are irrigated. These 760 million ha represent only 30 percent of the total land with rain-fed crop production potential, which is estimated to be 2570 million ha. The remaining 1.8 billion ha would therefore seem to provide a significant scope for further expansion of agriculture (Alexandratos, 1995).

Prevention of Losses Due to Insects, Pests and Diseases

Losses due to insects, pests, and diseases are too high. If we control insects, pests, and diseases, huge amounts of farm produce can be saved. Intensive use of land by reducing the fallow periods, more multiple cropping, and higher growth of the vegetable sector are contributing to the increase in population of insects and pests. This leaves farmers with the prospect of increased use of synthetic chemicals, leading to more resistance in insects; contamination of food by toxic residues; resurgence of pests; and detrimental effects on nontarget organisms, human health, and the environment (Dhall, 2001). More than 450 injurious species of arthropods have developed resistance to one or more pesticides because of repeated applications (Georghiou and Lagunes-Tejeda, 1991). Use of chemical insecticides and pesticides needs be decreased, and biological control of pests should be encouraged. Biological control should also be combined with integrated pest management. Host plant resistance should be increased through the production of transgenic varieties (Alexandratos, 1995).

Prevention of Post-harvest Losses

Produce can also be saved by reducing post-harvest losses, which are too high. The extent of these losses depends on the nature of food raw materials, that is, whether they are perishable, semi-perishable, or durable. In developed countries, technological advances in agricultural engineering have played a major role in the development of the agricultural and horticultural industries by providing the means to meet standards in terms of post-harvest handling and grading equipment, refrigeration systems, transportation, and packaging, as well as by developing equipment to assess and maintain quality (Studman *et al.,* 1994). Developing countries should also utilize the new post-harvest technologies and improve the food situation by considering the appropriateness of these technologies and adapting these to the local conditions.

Promoting Biotechnology

The integration of biotechnology into agriculture is growing rapidly and is particularly necessary for populated developing countries like India because it provides the necessary mechanism for increasing productivity (Chakraborty, 2001). It will help in increasing crop yields without the use of additional land (Kumar, 2002) and seems to be the only option left to enhance productivity per unit area where there is increasing demand for agricultural products from shrinking natural resources. Biotechnology can also assist in researching novel herbicides and weed management across commercially important crops and has proven to be an effective, economical, and safe tool for limiting the use of hazardous chemical herbicides (Ali, 2003). However, much research is needed to test the safety of genetically modified foods for the user and the environment.

Implications for Curriculum Reforms

In light of all the aforementioned issues, the curriculum in agricultural higher education should emphasize the demography of rural society and population dynamics; soil structure in relation to the physiology of plants and animals so as to extend the area under cultivation; dry land and wasteland management; and integrated pest management (Fig. 1). Research should be focused on developing new varieties having higher yields, better nutritive values, and enhanced resistance to insects, pests, or diseases. It should emphasize biological control by introducing new enemies of pests in an ecologically sound manner. Similarly, agricultural research should focus on post-harvest technologies such as innovations in storage in a controlled environment, development of silos, and processing technology for perishable products to increase their shelf life. Though conventional plant breeding methods have contributed a great deal, the scope of

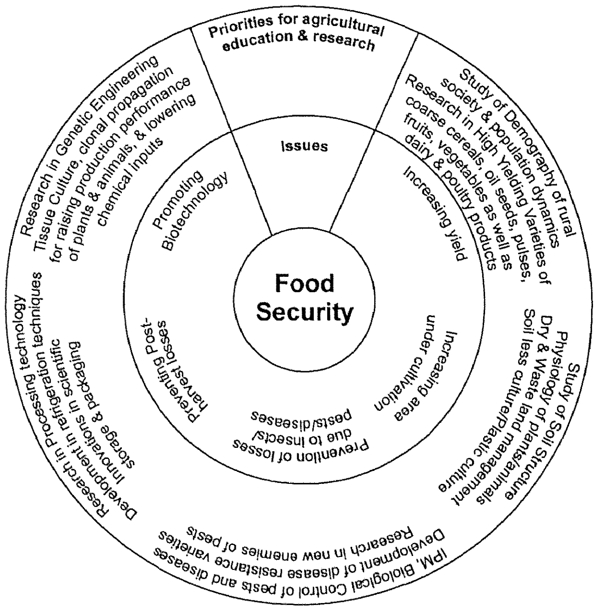

Fig. 1. Priorities for agricultural education and research to ensure food security.

biotechnology, genetic engineering, tissue culture, clonal propagation, and soilless culture should also be researched. Students should be well versed in the skills related to all these areas, and these should receive more emphasis in agricultural curricula to ensure food security for all.

Promoting Diversification

Agriculture has gone beyond raising crops and has diversified in various directions to include floriculture, horticulture, forestry, dairying, mushroom cultivation, silk production, fisheries, beekeeping, and rearing of small animals (e.g., pigs, rabbits, poultry). In areas where crop productivity is low, diversification in other enterprises could provide useful alternatives. In India and other countries with diverse agro-climatic conditions, there is a vast scope for producing commodities such as fruits, vegetables, flowers, culinary and medicinal herbs, and aromatic plants, which occupy a large portion of the national and international market. There is a great demand for raw material such as roots, bark, leaves, fruits, seeds, and their derivatives like oils and alkaloids all over the world.

Implications for Curriculum Reforms

To promote diversification, highly trained scien-

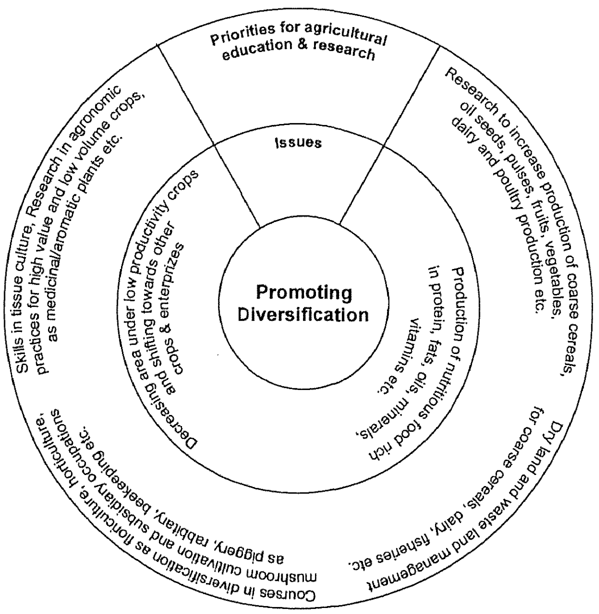

Fig. 2. Priorities for agricultural education and research to promote diversification.

tific manpower is required to develop technologies in all these specialized areas. Courses in diversification should be stressed in the curriculum of agricultural education. Agronomic practices for low-volume and high-value crops such as medicinal, aromatic, and other plants need to be emphasized. Graduates of agricultural universities should be skilled enough in different areas such as dairy farming, poultry, fisheries, bee-keeping, and cultivation of herbal plants to provide technical support to farmers and other individuals involved in such practices (Fig. 2). In addition, they also need to be equipped with necessary expertise to study marketing trends at the global level so as to ensure the economic viability of these enterprises. Agricultural students should be able to find self-employment in these areas rather than hunting after government jobs. Arrangements may be made for their on-the-job training at diversified farms. Research to increase production of nutritive foods such as coarse cereals, oil seeds, pulses, fruits, vegetables, and meat need to be promoted. Dry land and wasteland management should be given due attention to promote dairying, fisheries, bee-keeping, and rabbitry.

Sustainability of Ecosystems

Due to increasing population, urbanization, industrialization, and intensive agriculture, the soil, water, and other parts of the environment have degraded severely. The Human Development Report (2007) showed that climate change is not just a future scenario. There is now overwhelming scientific evidence that the world is moving towards the point at which irreversible ecological catastrophe becomes unavoidable. The conservation of the Earth's biological resources and biodiversity is a great challenge for agricultural scientists. They are confronted with the important and apparently contradictory twin tasks of satisfying the present needs while keeping in view the future. The main issues that need attention are degradation of soil, contamination and depletion of water resources, and overuse of chemicals.

Degradation of Soil

Intensive agriculture is causing soil degradation via erosion, increases in salinity, and loss of nutrients. In developing countries nearly 1 billion ha of arable land are estimated to be so degraded that productivity is being moderately to severely affected. Some 9 million ha worldwide, of which 5 million ha are in Africa, have had their original biotic functions fully destroyed and reached the point where rehabilitation is probably not economically feasible (Alexandratos, 1995). Efforts need to be made to improve nutrient content and the physical properties of soil such as granulation, tilth, aeration, and water holding capacity by replacing chemical fertilizers with organic or biofertilizers. Mixed farming systems can also help in recycling of farm wastes, thereby reducing the cost of production, improving soil structure, and decreasing farmers' dependence on chemical fertilizers.

Contamination of Water

The quality of water is deteriorating due to the rise in salt concentration from effluents from industries and cities. According to Falkenmark and Widstrand (1992), the combined effect of population and economic growth will exert increasing pressures on freshwater supplies. Agriculture is the dominant water use, accounting for nearly 70 percent of total consumption of managed water resources, compared with about 21 percent and 6 percent for industrial and domestic use, respectively.

Pollution of Air

Air has been polluted through the emission of gases such as carbon dioxide, methane, chlorofluorocarbon, and ammonia, leading to global warming. Despite warnings, farmers continue to burn paddy and wheat stalks. Due attention must be given to take measures against burning of straw by the concerned authority. Some of the air pollutants are seriously and adversely affecting peoples' health.

Overuse of Chemicals

Farmers use excessive insecticides and pesticides as insurance for high-value crops, especially vegetables, to enhance the cosmetic appearance. According to Paroda (2001), less than 1% of pesticides applied to a crop reaches the target, while the other 99% remains in the environment and causes pollution. In the mid-1980s, developing countries accounted for about 20% of the global consumption of fungicides and 50% of the pesticides used (Alexandratos, 1995). Chemicals used in excess pose numerous risks to humans, animals, and the natural predators of pests.

Implications for Curriculum Reforms

Agricultural research, education, and development systems have to take the necessary steps for the conservation of soil and water resources and prevent the overuse of chemicals before it is too late. Traditional approaches of higher education in agriculture fall short in dealing with sustainable agriculture. Courses on sustainability to safeguard the productive potential and environment for future generations while satisfying food and other needs should be an integral part of the curriculum. Research in biological control of insects and pests, biopesticides, transgenic crops, integrated pest management, integrated nutrient management, and water management needs to be intensified. Low-cost technologies for the degradation of biomass into organic manure and efficient irrigation designs need to be developed (Fig. 3). These technologies need to be continuously updated and taken to farmers' fields in a useable form to save the natural resources of soil, water, and air.

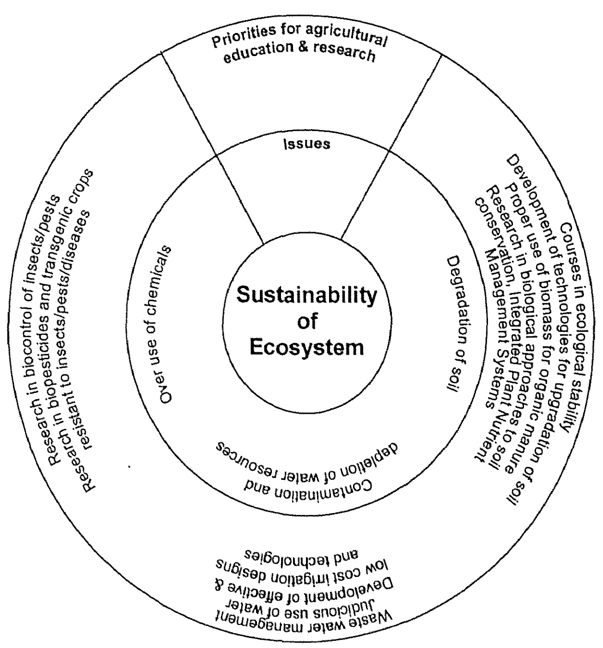

Fig. 3. Priorities for agricultural education and research to promote sustainability of ecosystems.

Promoting Agro-Processing and Agribusiness in the Context of Globalization

With the increase in population, land resources are continuously shrinking and many farm families are left without any productive assets. As a result, many rural people are shifting to urban areas in search of employment. This problem can be overcome by establishing agro-processing industries in rural areas based upon the local strengths and potential. Due to globalization and liberalization, agriculture is no longer concerned with food production only; it has been transformed into a commercial industry instead. However, most small and marginal farmers are unaware of prospects of agribusiness and are reluctant to deviate from their traditional role. If the farmer is to benefit, he/she must be educated about agribusiness to promote it domestically and internationally. Through agribusiness, farmers can earn more profits rather than dispersing the produce at throw-away prices during peak seasons. Farmers must be trained in agribusiness, while keeping in view consumer's preferences. The major objective of education must be the creation of an entrepreneurial and innovative society (Sinha, 2002).

Implications for Curriculum Reforms

Competent agricultural graduates can play an important role in creating a society well versed in knowledge and technical know-how of processing and agribusiness. Agribusiness should be introduced as a subject in the curriculum. Students should be familiar with the trends in the domestic and international market and have knowledge and skills in all aspects of agribusiness. Only competent agricultural graduates would be able to pay back rich dividends to society and earn for themselves substantially more than the investments made. Scientists must develop post-harvest processing technologies that could be used by farmers at the village level. Agricultural graduates should use their knowledge and skills to establish viable enterprises in rural areas, which will also generate self-employment, jobs, and prosperity. To enable graduates to keep in touch with the latest developments in science, technology, and marketing trends, students need to acquire the necessary knowledge and skills in computer applications and information technology as well. The traditional attitude of farmers needs to be changed through training, of which agribusiness should become a major aspect (Fig. 4).

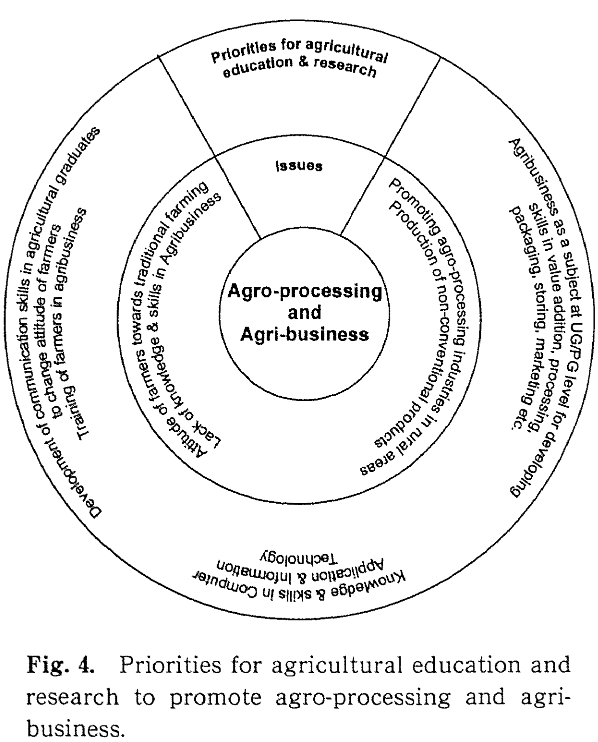

Fig. 4. Priorities for agricultural education and research to promote agro-processing and agribusiness.

Revamping the Extension System

Agricultural extension programs bridge the gap between technical knowledge and farmers' practices. Without technical assistance, information, and training, farmers are limited in their ability to adopt new technologies, which results in lower crop yields and may lead to environmental degradation. Extension services can have great importance for agricultural development, and high rates of economic returns from investment have been demonstrated. A study of agricultural extension by Evenson (1982) reported that in the United States a $1000 increment in extension spending was associated with a $2,173 increase in farm output within two-year period. Similarly, a study on World Bank support to agricultural extension services in 22 sub-Saharan African countries reported an average of 40% increase in yields in the first year (World Bank, 1992). However, the actual coverage of agricultural extension services in the developing countries is limited. In 1990 in the United States, Canada, and Europe, one public extension agent covered about 400 economically active persons in agriculture, whereas in developing countries, an extension worker covered an average of about 2,500 such persons (FAO, 1990).

Implications for Curriculum Reforms

The agricultural extension system needs to be revamped, and it should be a bottom-up instead of a top-down system. Extension agents are involved in conducting surveys, but their participation in the formulation of reports or planning is either weak or ignored by researchers and policymakers. Linkage and coordination among various organizations, extension workers, and researchers needs to be increased. Extension workers should have communication skills and positive attitudes towards the farming community. Farmers should be a part and parcel of the agricultural planning and implementation from the very beginning, because through their involvement the acceptability and diffusion of technology will be much faster in the social system. Farmers' active involvement in the system will lead to a stronger desire for change. Extension programs should be directed towards assisting farmers not only with the technical aspects of production and processing, but also with economics and the marketing of products.

In the future, the emphasis will have to be changed from a "transfer of technology" approach to "farmers first" and "participatory extension" approaches. Instead of giving blanket recommendations for all farmers, extension workers will have to study the realities on the ground and the problems of each farm and suggest appropriate farming systems while considering the actual physical, economic, and social conditions. This will require skills in studying problems at grass-root levels, and agricultural education needs to be reoriented accordingly. Extension programs should also be aimed at increasing the number of female agents by providing them with access to training, teaching technical subjects to females, and providing more facilities to them. The content of extension services to women farmers should be improved by including messages and recommendations that are relevant to women's productive activities. Male extension agents should also be sensitized to work with women farmers (Fig. 5).

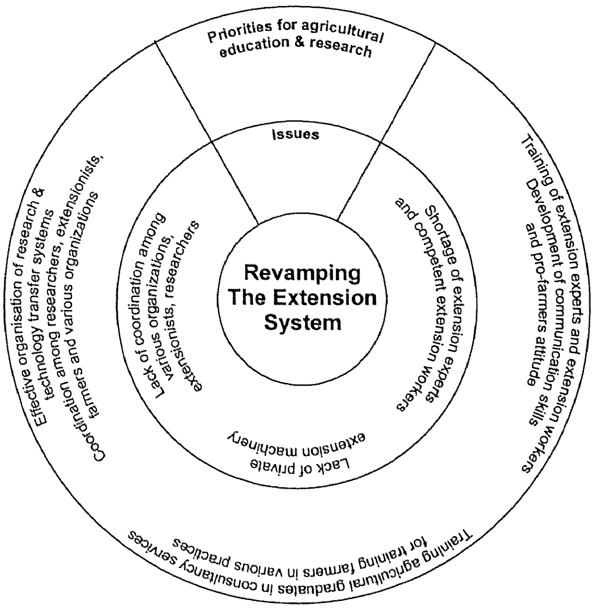

Fig. 5. Priorities for agricultural education and research to revamp the extension system.

Conclusions

In the context of the above discussion, the course curriculum of agricultural higher education needs to be made more broad based by including courses in areas such as biotechnology, agribusiness, agrometeorology, computer application, information technology, environmental science, agro-ecology, conservation of natural and human resources, and trade and export in agribusiness.

Changes in course content need to account for the various requirements of the 21st century in the context of liberalization and globalization. On-the-job training at research farms and on farmers' fields should be an integral part of education both at the undergraduate and postgraduate levels. In order to improve the quality of research at the postgraduate level, due weight in determining academic achievement needs to be given instead of considering research as only non-credit requirements. Agricultural universities should adopt the suggested reforms, with modifications to accommodate local conditions.

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