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Food Security in the New Millennium-I: The Role of Agricultural Biodiversity

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Abstract: This paper describes the concept of agricultural biodiversity and its importance in present and future food security. Some facts and figures are being presented in order to apprise the reader about the state of agricultural biodiversity in this country and elsewhere. The term agricultural biodiversity has been elaborated at length with special reference to the type of biodiversity available in Pakistan. The importance of biodiversity has been discussed in relation to its role in value addition to commercial crops in the form of resistance against pests and diseases. Its contribution, to human foodstuff, removal of genetic vulnerability and food security has also been discussed in detail. How agro-biodiversity has been utilized in crop production programmes and how rapidly it is being eroded, has also been described. Emphasis has been made on the conservation (both *in situ* and *ex situ*) of sites rich in agro-biodiversity along with its characterization and utilization in order to enhance its present status and to create new biodiversity to meet the future demand of crop improvement especially for tolerance to abiotic stresses.

Key words: Agricultural biodiversity, crop production, food calories, food distribution, food security

Introduction

Global food production, that increased rapidly over the past 30 years, has helped outstrip population growth. Yet today, in a world that has the potential to supply an adequate diet for all, millions of people remain hungry. The green revolution has helped increase the yield of the staple crops from 1.06 to 2.50 metric tones per hectare (UNEP, 1995a), but food security remains an unfulfilled dream for about 800 million undernourished people. Pakistan's share of undernourishment is 26.3 million people that represents 31, 20 and 19% of population for the duration of 1978-81, 1990-92 and 1995-97, respectively (FAO, 1999a). These figures are almost equal to the average reported for the developing countries in general. The problem of food insufficiency is especially chronic in countries with low income a greater part of which comes from agriculture. As long as this situation prevails, eliminating hunger and ensuring food security would require concerted efforts to accelerate agriculture and rural development in these countries. A Second green revolution will be required to increase yields not only of wheat, maize and rice but of other important food crops such as sorghum, millet and cassava that are consumed by many (Leary, 1996). It would also be essential to practice sustainable agriculture by protecting resources such as biodiversity, land and water from becoming increasingly eroded, degraded and polluted, respectively. At the same time developing countries can explore new ways to help meet the food needs. These measures include improvement and extension of agricultural activity on marginal lands, rediscovering forgotten food and encouraging urban agriculture. Collectively, all this may help alleviate poverty and ensure future food security. In present review article, some facts and figures are being presented in order to apprise the reader about the state of agricultural biodiversity in this country and elsewhere, its significance and importance for food security and its role in improvement of crops and other agricultural activities especially on degraded lands situated in the areas where poor lives.

Concept of food security: Food and Agriculture Organization of the United Nations has defined food security as a "state of affair where all people at all times have access to safe and nutritious food to maintain a healthy and active life". During the last 50 years, however, food security has progressed from purely physical availability to provision of food to individuals at global level. According to Swaminathan (1999), food security is a multi-objective phenomenon dependent on intricate social, cultural, economic and political relationships that differ enormously between and within the countries and with changing time. Agriculture itself, food policies of a particular country, feasible economic factor(s) and their interaction at micro and macro level play major role in determining the access to food and are hence the limiting factors. Therefore, availability of food at local or global level as such is not the real problem. Rather, it is the management of food supplies in complex political emergencies characterized by social and policy breakdown. It is concerned with the complexities of livelihood strategies in difficult and uncertain environment and understanding of the people themselves in responding to risks and uncertainties.

For food security, flexibility, adaptability, diversification and resilience are the key factors. Ensuring food security is perhaps the greatest challenge facing the world community today. It is a complicated phenomenon in which those facing food insecurity will have to decide themselves how better they can attain food security while keeping in mind their social and economic constraints. A country and the people can be food secure only when their system operates in such a way as to remove the fear that there will not be enough to eat next time. The challenge therefore, is most critical in low income, food deficit countries. Achieving sustainable increase in food production may help relieve the fear of food insecurity in countries like Pakistan, with predominantly rural populations that largely depend on agriculture as a source of livelihood.

The current agricultural production per capita is more than 20% higher than it was 30 years ago, while the consumption per capita and the population have increased by 17 and 67%, respectively (UNFP, 1996). Pakistan is consuming 2460 calories per capita per day (FAO, 1999b), which is approximately 6% better than the average in South Asian countries (Alexandrator, 1995). Also, the current world consumption has increased by approximately 17% in 30 years (Table 1) suggesting that enough food is available at the global level to ensure food security to everyone provided the food is distributed equally.

This, however, is not the case. The industrialized countries are consuming 3330- cal/capita/day while Sub-Saharan Africa is consuming 2040 cal/capita/day, which is 3% less than it was consuming in 1960-62 (Table 1). This indicates that food production is not in line with the population growth. Therefore, despite adequate availability of food at the global level, food security cannot be assured unless production is increased at local level. This is particularly imperative for the developing countries where availability of foreign exchange for imports is a major limiting factor. For low income and food deficit countries like Pakistan, importing food would be a luxury especially when economy is largely dependent on borrowed capital and deficit in balance of payment is around 4.03% of the GDP compared to 0.61% of the developing countries and 0.57% of the Asian countries (Anonymous, 1999a). Under such circumstances, it is imperative to increase local food production through policies and programmes in agriculture, resource management and economic development. Presently, the situation on the ground is that the

Table 1: Distribution of food (measured as calories/person/day) in different parts of the world

Region	1961-63 (a)	1990-92 (b)	2010 (c)	% increase (a-b)	% increase (b-c)
Developing countries	1960	2520	2730	28.57	08.33
Sub-Saharan Africa	2100	2040	2170	-3.00	06.37
East Asia	1750	2670	3040	52.57	13.86
South Asia	2030	2300	2450	13.30	6.52
Industrial countries	3020	3330	3470	10.25	4.20
World	2300	2700	2860	17.39	5.92

Source: World Agriculture towards 2010 (Rome), (Alexandratos, 1995)

Table 2: Current status of plants species

No. of species	Status
320,000-500,000	Reported to be available on the planet earth
50,000	Known and collected as edible species
7000	Collected for food
3000	Being used for food
123	Known to provide 90% of plant energy
15	Known to provide maximum plant energy
3*	Staple food of nearly 2/3 of the world's population

*Wheat, Rice and Maize.

GDP of the country remained lower (2.6%) than the lowest forecasted (2.9%) by the World Bank (Anonymous, 2001a) for the developing countries in aftermath of September 11. Wheat harvest for the year 2000-2001 remained at 18.73 million tones, which is 11% less than the harvest of 1999-2000 and another 5% reduction is expected during 2001-2002. The deficit would be met either through down draw from reserves or through imports. Similarly, rice production remained at 3.9 million tones and was 24% less than that of 1999. It is also expected to go down further in the year 2001 due to severe shortage of water especially in the provinces of Sindh and Punjab (FAO, 2001, 2002). Since the economy of country is dependent on agriculture, reduced agricultural productivity during the last couple of years has significantly affected the GDP: the growth of which, remained at 2.6% during 2000-2001 compared to 3.9% during 1999-2000. This collectively has raised poverty to the level of 33.5% in the year 2000 (FAO, 2002). Since, food security in Pakistan and similar other countries would largely depend on sustainable rise in agricultural productivity, it is imperative that soil, water and biological resources be managed effectively and concerted efforts be made for rural development, developing of new crops and for improvement of production technologies (Bojo, 1991; Brown, 1997).

Agricultural production technologies: Crop production can be increased by two methods i) modern biotechnology (including the hardcore genetic engineering) and ii) the classical biotechnology (including wide hybridization). Both the approaches depend on genetic resources or agricultural biodiversity or agro-biodiversity. In modern biotechnological approaches, genetic resources like plants, bacteria, fungi and viruses are used. The entire technology is protected through patents, making it investment intensive to start with. The technology does have the promise, but is beset with environmental concerns and the fear of dependence on foreign companies. This technology may not spread easily in the poor and food deficit countries because it does not meet the requirement of small farmers. Since in developing countries, majority of the farmers are resource deficient and poor, they cannot afford heavy investments in terms of i) importing expensive proprietary herbicides and pesticides and ii) royalties as patent compensation. Therefore, the technology suits affluent landlords alone and not to the small farmers who are in great majority (for greater detail, pl. see part II of this review). Efforts made by some countries on developing biotechnology mediated large-scale commercial agricultural production for export never worked. Instead, commercial agricultural production forces many of the small farmers to sell their land to a bigger enterprise (Brown, 1996). It has been generally realized that use of new, improved varieties of crops and better production technology would be slow to spread unless they respond to local needs and unless local farmers are involved in introducing them (Valente, 1995).

In classical agricultural biotechnology, only the genetic resources of plants are used. It needs collection and evaluation of exotic and wild germplasm to identify the gene (s) of interest that can be incorporated through crossing into the existing varieties. These varieties can then be tested and selected at different locations to see the expression of character (s) transferred from the exotic or the wild species. The technology so far is not patent protected and is therefore, devoid of dependency. However, it does not require heavy investment and can therefore, meet the requirements of the country and the farmers. Being environment friendly, it can be adopted without any fear. The biggest requirement of this technology is free access to agro-biodiversity and its related knowledge. Although highly threatened by globalization and industrial food production, this can still provide livelihood security to billions. Agro-biodiversity is therefore, a cornerstone to all food production including that of agriculture and biotechnology (life) industries.

What is agricultural or agro-biodiversity?: Agriculture biodiversity is a relatively new term and has come into wide use in recent years. It is defined as the variety and variability of animals, plants and micro-organisms which are necessary to sustain key functions of an agro-ecosystem, its structure and processes, for and in support of food production and food security (FAO, 1999c). It also comprises variety and variability of animals, plants and microorganisms, diversity of genetic resources (varieties, breeds, etc.) and species used for food, fodder, fiber, fuel and pharmaceuticals. It includes harvested crop varieties, livestock breeds, fish species, non-domesticated (wild) resources within field, forest and rangeland and in aquatic ecosystem. It also includes the diversity of non-harvested species that support production (e.g. soil micro-organisms, predators, pollinators etc.), agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems themselves. It is the result of careful selections and inventive developments of farmers, herders and fishers over millennia. It results from the interaction between environment, genetic resources and the management systems used by culturally diverse people. Agro-biodiversity is a vital sub-set of general bio-diversity and a creation of humankind whose food and livelihood security depend on the sustained management of diverse biological resources that are important for food and agriculture. Agricultural biodiversity (or genetic resources) in combination with physical environment and human management practices, collectively determines agro-ecosystem. Their interaction that may involve, introgression of genes from wild relatives, hybridization between cultivars, mutations and natural and human selections determines the evolutionary process. This evolution results in genetic material (crop varieties or animal

Table 3: Agro-biodiversity documented from different provinces of Pakistan*

Category	Types	No. of species	Locality
Cereals	Rice	1850	Punjab and Sind
	Wheat and wheat relatives**	1749	Punjab and Balochistan
	Sorghum	622	Punjab and Sind
	Millet	769	Punjan
	Barley	967	Punjab
	Oat	272	Punjab and Balochistan
Forages	All types	171	All over Pakistan
Flowers	Ornamentals flowers	145	Punjab, N. Areas and Balochistan
	Ornamental perennials	170	All over Pakistan
Fruits	Mixed fruits	700	N. areas, Punjab, Sind and Balochistan
	Citrus (9 species)	> 100 varieties	Punjab
	Mangos	> 60 varieties	Punjab and Sind
Medicinal Plants	All types of annual and perennials	~ 548	All over Pakistan
Oil seeds	*Brassica* (Toria, Saroon, Tarameera and Sesame)	148	Punjab and Sind
	Crucifers	178	Punjab and Sind
	Cotton*** *herbaceum* and *arborium*	> 171	Punjab and Sind
	Maize All types	100	Punjab, Azad Kashmirand N. Areas
Pulses	Chick pea, lentil and Mung bean	2449	Punjab and Sind
Perennial flowers	All types	170	All over Pakistan
Trees	All types	118	All over Pakistan
Vegetables	All types	> 539	All over Pakistan

*A large number of accessions of cereals and legumes are available in Plant Genetic Resources Institute (PGRI), Pakistan Agriculture Research Council (PARC), Islamabad, Pakistan, ** Naked wheat was grown in Balochistan since 6000 years BC,
*** Central Cotton Research Institute (CCRI), Multan is maintaining about 1600 accessions of different cotton species. The oldest cotton yarn was unearthed in 5000 years BC from Mohenjodaro, Pakistan

breeds) that is well adapted to local biotic and abiotic environmental variation. Agro-biodiversity and human activities are therefore, indispensable for each other, for progress and evolution and for provision of food and other necessities of life. Both are essential for the maintenance of the areas and of the environment that sustains them.

Where, how much and who possess agro-biodiversity?: Africa, Latin America and Asia are poor but diversity-rich countries of the South possessing about 83% of the total agro-biodiversity as *in situ* germplasm. Northern countries, on the other hand, possess only 17%. However, their share of the world total *ex situ* diversity is about 75% and is available in different gene banks of which 22% are located in the North. These gene banks contain about 55% of all the seed accessions and 62% of all crop species collected from the Southern countries. Over 40% of all the accessions in these gene banks are of cereals (FAO, 1996a), while food legumes constitute only about 15% of the global *ex situ* collections. Minor and subsistence crops, farmers' varieties (land-races), their wild relatives and non-domesticated species vital to subsistence farmers and food security of millions of poor people in the South are grossly under-represented in gene-bank collections. For example, cassava, a major poor people's crop, accounts for only 0.5%. Vegetables, roots and tubers, fruits and forages each account for less than 10% of the global collections. About 0.18% of the total accessions of yams (11,500) and still fewer of bananas and plantains (10,500 accessions) are represented (Wilkes, 1993). Since, cereals play a dominant role in food security worldwide, disproportionate share held in gene banks reflects the fact that cereals are the most important species for trade in Northern agriculture. While this collection was made prior to the convention on biological diversity (CBD), it is currently beyond the reach of the CBD and is thus the property of the North.

The *ex situ* share of Southern countries is 25%, which depends only on the resources in the large gene banks of CGIAR (Consultative Group on International Agricultural Research) located in the South but controlled by the North through scientific boards and funding agencies. For half of all the accessions in these gene banks, there is no information available to judge whether it is a farmer's variety, a land-race, wild relative of a crop, or a cultivar developed by the Institutional breeders. FAO's database reveals that 48% of all these accessions are cultivars or breeding lines, 36% are farmers' varieties (land-races) and only 15% are non-domesticated plants or crop relatives (UNNRC, 1993). According to the agreement of 1994 between FAO and CGIAR, this material has been categorized as " in-trust" material that is to be maintained in public domain and is not subjected to any intellectual property rights. About 30-40% of this material, is among the world's most important seed stock and is now fetching about US$ 5 billion annually to the industrialized/developed countries in the North. Only the cost-benefit ratio for two most important cereals that is wheat and rice was US$ 1-190 and 1-17, respectively in 1996. Among the other crops originated in South including tomato, sorghum, maize, beans, barley and soybean contributes about US$ 5, 12, 20, 60, 150 and 500 millions per annum to the US agriculture (Anonymous, 2001b).

Agro-biodiversity: Why it is so important?: Agro-biodiversity or plant genetic resources can produce wonders because they i) add value to crops, ii) induce resistance, iii) contribute enormously to human foodstuff, iv) remove the fear of genetic uniformity and vulnerability and v) are responsible for the food security of the world.

I) Value addition: Industrial agriculture depends on exotic germplasm to develop and release new varieties to stay one step ahead of thousands of pests and diseases that attack the varieties as soon as they are introduced into the field for commercial cultivation. Without access to exotic germplasm, industrial agriculture would literally grind to a halt. Improvement of only soybean and maize crops through exotic germplasm added value of US$ 3,200 and 11,000 million, respectively to the annual revenue collected earlier for these crops that was about US$ 7,000 and 18,000 million, respectively (FAO, 1996b). In addition to exotic germplasm, the genes from wild species are also enormously valuable. The estimated contribution of wild germplasm to the US economy amounts to $ 340 million per year during 1976 and 1980 in terms of yield and disease resistance. A single wild tomato species contributed valuable genes to tomato and added value worth US$ 8 million per annum to US tomato processor (UNEP, 1995b). The estimated benefits of exotic germplasm for durum wheat amount to US$ 300 million per year in Italy alone.

ii) Induction of resistance: The resistance against army-worm identified in the exotic germplasm of maize from Mexico, the Caribbean and Brazil and transferred to a commercial maize has saved US$ 30 million worth the damage caused to the US maize annually (USDA, 1993). The commercial sunflower industry of Australia, China, South Africa, India and the United States, threatened by new races of rust, have now been saved by transferring resistance genes from an ancient sunflower variety cultivated by Indian farmers in South-Western USA. AgrEvo (a German agrochemical company) achieved genetic tolerance for its best selling herbicide glufosinate through introduction of one of its two resistant genes derived from a soil sample obtained from Cameroon. AgrEvo is one of the industry's leading developers of transgenic herbicide tolerant plants. Herbicides accounted for 45% of AgrEvo's US$ 2,200 million sales in 1994 (Heissler, 1995).

iii) Contribution to human foodstuff: World statistics (Table 2) indicate that out of 50,000 varieties of edible plants discovered so far, only 15 are responsible for 90% of the world's food energy intake (World Bank, 1996). Among them, rice, wheat and maize are the staple foods for nearly two-third of the world's people (UNEP, 1995a; FAO, 1996c). Few other crops generally considered as poor man's diet such as barley, sorghum/millet, potato, sweet potato/yam, sugarcane and soybean are also exploited for food but their importance is generally masked by the industrial crops. There are about 320,000 species of vascular plants available in low income and poor countries of the South of which, about 3,000 species (both wild and domesticated) are regularly exploited as food (FAO, 1996d). Among them, the total collected for food however, exceeds 7,000 (Anonymous, 1994) of which 103 species are considered responsible for supplying 90% of the world's plant food supply (Robert and Allen, 1990). With current food production, which is 11.3 trillion K cal. (Kern, 1998) and with current average food consumption, which is about 2700 cal./day/person (Southgate and Basterrechea, 1992), it is possible to feed 8 billion people. However, the anticipated increase in the demand of calories intake in the developing countries as a result of their breath taking economic growth (particularly in Southeast Asia), there will be a deficiency of about 7.4 trillion K.cal. This deficiency can be overcome if crops other than present day staple crops are encouraged for food. If the three crops (wheat, maize and rice) can provide 50% of our total energy intake (UNEP, 1995a; World Bank, 1996), the potential of other crops is certainly beyond realization. The present day commercial agriculture depends only on a handful of commodity crops that are being reinvestigated continually to enhance their agronomic potential thinking that humanity depends only on these crops, which is not the case. Such mistaken decisions had played significant role in undermining the food security of the poor and increasing the specter of hunger in many areas of the world. This is because, for poor people in marginal farming areas especially of the South, survival depends not just on rice, maize and wheat, but on minor species that are adapted to harsh climates and poor soils and that have been neglected or ignored by institutional agricultural research.

iv) Removal of genetic uniformity and vulnerability: The success of industrial agriculture is based on genetic uniformity and capital-intensive inputs like irrigation, fertilizer and pesticides to maximize production. Expanding genetic uniformity could be disastrous as it is more vulnerable to epidemics of pests and disease. The Irish potato famine of the 1840 is a textbook example of genetic uniformity. In the year 1500, potatoes that originated in the Andes Mountains of South America were introduced to the New World. However, none of the introduced varieties proved resistant when a fungus struck Ireland's potatoes in 1840. The entire potato crop was wiped-out leaving behind over 1.5 million people dead in the famine. In 1970, genetic uniformity of maize crop grown in United States was responsible for destroying maize crop worth almost US$ 1 billion and reduced the yield by as much as 50% just because at the time of epidemic, about 80% of the maize varieties grown were carrier of a gene susceptible to a virulent disease known as Southern Leaf Blight. Even today, the priorities with regards to genetic vulnerability and food stability strategies are certainly deficient, if not non-existent (Wilkes, 1993). In South, enormous genetic diversity in rice, wheat and maize has steadily eroded due to continuous growth of only few high yielding Green Revolution varieties. Bangladesh is one such example where Green Revolution varieties covered 96% of the wheat area in 1984 of which 67% was planted with just one variety (UNNRC, 1993). Similarly, two rice varieties developed at IRRI, Philippines, covered about 90% of the entire rice growing area in the dry season of 1984 (FAO, 1996e), which resulted in rapid growth of rice diseases and pests in number, intensity and geographic distribution.

v) Contribution to human food security: Crop genetic diversity adapted to a particular environment determines the requirement of fertilizers, pesticides and irrigation for that very climate. The farmer communities not relying on locally acclimatized varieties loose the control of the farming system and become dependent on the outside resources for seed and the other required inputs. Hence, their food security will go in the hands of those who provide the resources. The local genetic diversity: a vital source for long term sustainability in agriculture and self-reliance and for the stability of global food supply will be lost. About 60% of the world's agricultural land, mostly in the marginal area (David, 1993) is still farmed by traditional or subsistence farmers who meet all their food needs from such lands (Berg, 1995). Since, the green revolution varieties perform best in rain-fed and irrigated regions, the proponent of the technology never considered the resource poor but diversity and knowledge rich indigenous farmers of marginal areas and less hospitable farming environment that is not suitable for these varieties (Berg, 1996). Self-reliance in food production for the majority of the world's farmers therefore, depends on adapting technologies and germplasm to a wide range of poor production environments and the diversity adapted to that, which has largely been eroded in the South due to spread of these commercial high input varieties.

Agro-biodiversity: International legal binding and concerns of the developing countries: Historically, the access to plant genetic resources has been free. Therefore, plant genetic diversity found in the farms, field and forests of the South as well in tropical centers of diversity was freely collected and stored in the gene banks established by CGIAR. Later, this material comprising half a million seed accessions was introduced in the industrialized world as the "raw material" for plant breeding that has been increasingly commercialized and controlled by transnational seed and agrochemical corporations. This situation led to the development of "Plant Breeder Rights: a monopoly right given to the breeders for production, marketing and sale of their varieties for a period of up to 25 years. Through Plant Breeder's Rights, seed companies promoted innovations in plant breeding, while collection of royalties enabled them recoup their investment in plant biotechnology. The current form of Plant Breeder's right is intellectual property systems, which enables the agriculture biotechnology industry to have greater control over seeds and germplasm albeit with serious impacts on farmers, food security and plant genetic resources. Intellectual property regimes generally deny farmers the right to save and propagate their seeds, prohibit researchers from using proprietary germplasm (even for non-commercial purposes) and thus profoundly restrict access to and exchange of germplasm. Thus the germplasm, that had been collected form South and was stored in the gene banks of the North as their property, is now being used as raw material by the industrial plant breeders to develop new varieties without compensating the original donor. Most of this raw material is still available as *in situ* germplasm in the countries from where it was originally collected. However, these countries may not be able to use it the way it is being used in the industrial agriculture unless they pay heavy royalties to those who patented the process of using this raw material and the product obtained as a consequence of this utilization. Thus, the poor farmers of the South who are the actual custodian and innovator of the diversity that is fetching US$ 5 billion annually to the industrialized countries of the North have now been deprived of their own heritage. As presented some time ago, in "Biodiversity Balance Sheet" prepared in 2000 by RAFI (Rural Advancement Foundation International: an NGO based in CANADA) the dominant role in agriculture and *in situ* technology of countries in south cannot be ignored because these countries possess 86% of the known higher plants, 99% of the world indigenous people and 96% of the farmers. For standard or classical biotechnology, they can also do reasonably well as they have more than 1/3rd of the world agronomists and 1/5th of the plant tissue culture specialists. The future of world food security is dependent on these resources. However, the infrastructure of high technology agriculture research in these (agriculture resource rich) countries is severely limited. This situation has seriously undermined the food security of millions of poor farmers responsible for maintaining and nurturing the genetic diversity for ages. FAO (1993a) established a commission on "global system for conservation and sustainable use of plant genetic resources" aiming at i) conservation of plant genetic resources, ii) sustainable use of its components and iii) fair and equitable share of the benefits arising from the utilization of genetic resources. Nevertheless, commission's international "undertaking on plant genetic resources" is a non-binding agreement that establishes only the guidelines for the use and exchange of genetic resources, subject to the sovereign rights of nations over the genetic resources in their territory. This undertaking that recognizes both Plant Breeder's and Farmer's Rights was to be revised in harmony with the Convention on Biological Diversity (CBD) which came into existence almost 10 years after the founding of FAO's Commission on Genetic Resources. CBD on the contrary, provides an international and legally binding framework for the conservation and sustainable use of bio-diversity worldwide. An international undertaking, that contains a set of legally binding provisions covering ownership, access to and exchange of plant genetic resources, is now being revised through negotiations between countries. The major hurdle in these negotiations is the reluctance of the seed companies to acknowledge the Farmer's right. It is this instrument that will establish the rules of the game on access to agricultural bio-diversity. The revised "international undertaking" was to be considered as a protocol to the Convention on Biological Diversity held in Nairobi, from May 16-26,2000, but unfortunately, the decision about the fate of the farmers' right and access to PGR has not yet been decided.

Where do we stand?: Pakistan is blessed with a wealth of genetic diversity, wild and cultivated plants of crops, vegetables, fruits, ornamental plants, perennial trees, cereals, medicinal plant (Table 3) and unique breeds of animals and birds. A part of this diversity may have already been collected and is deposited in the gene banks. This diversity is the main source of providing food, feed and fodder to millions living in the native areas. It is imperative therefore, that the diversity native to this country is collected, evaluated and utilized in the crop improvement programme in order to strengthen the basis for sustainable agriculture production. With increasing population, the demand in calories would automatically increase. To meet this challenge, either the productivity per unit area or the area under cultivation will have to be increased. The later is possible only if the areas that are either degraded or beset with salinity be utilized. This would require new varieties developed for a particular stressed environment that is possible if the diversity native to this land is used for the production of new varieties. Plant Genetic Resources Institute (PGRI) is the only public sector institute responsible for collection, management and evaluation of the exotic and wild germplasm available in the country. The institute is currently maintaining 15,000 accessions of different crops partly mentioned in Table 3. Some of these accessions have already been collected by the international agencies through the international expeditions. The need of the day is to collect, preserve (*ex situ* and *in situ*), evaluate and utilize this bio-diversity for enhancing the existing potential of our productivity.

The most effective way to improve crop plants for traits such as disease and insect resistance and increased tolerance for drought and saline soils is through hybridization of domestic varieties with their wild relatives (Zamora, 1996; FAO, 1993b). Utilizing agronomically important genes through wide hybridization is a tried and trusted way of improving agricultural productivity to meet the challenges of food security in the current millennium.

The options for Pakistan and other diversity rich counties: As described earlier, one of the major negative impacts of the Green Revolution is the erosion of genetic resources vital for the food security especially of the farmers native to the diversity rich areas of a particular country. Pakistan is one of such countries endowed with a wide variety of plant species, that are to be conserved and utilized as a prerequisite for sustainable agriculture production and to ensure the stability of the food production system of the rural population (Anonymous, 1999b).

Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, is the only institute in the country working extensively on utilization of genetic resources. Of particular significance is the work on improvement of salt and drought tolerance in wheat and rice using diversity available in the wild relatives of these crops (Farooq *et al.*, 1989; 1992; 1994a,b; Farooq, 1996). The material has been collected from different germplasm centers of the world including some of the accessions native to Pakistan. The material was maintained, multiplied, evaluated for different characteristics and fingerprinted using different markers. The identified wild species generally belonging to wild progenitor (*Aegilops* species) of cultivated wheats (*Aegilops geniculata* and *Ae. cylindrica*) were used to transfer gene(s) for biotic and abiotic stresses into wheat (Farooq *et al.*, 1998). NIAB is the only research Institute in the world using *Ae. geniculata* and *Ae. cylindrica* as gene source for salt tolerance. The wheat material produced in this programme is being utilized at CIMMYT (Mexico), Bangor (UK), Zaragosa (Spain) and other saline areas of the world. It is reported to be one of the best wheat materials produced for saline areas as it is giving good agronomic yield on saline lands (Anonymous, 1997; Farooq, 2002; Farooq and Azam, 2002). Efforts continue to conserve agronomically important gene(s) residing in the wild species of wheat and rice into commercial cultivars in order to create agro-biodiversity for sustenance of agriculture in times to come.

Wild germplasm of cotton native to this country is also being maintained and utilized for improvement of cotton cultivars. Central Cotton Research Institute (CCRI) in Multan (a large public sector institution) is working in this direction through the use of cotton genetic resources. The institute is currently maintaining 1600 accessions of cotton some of which are native to Pakistan (Anonymous, 1998). The Institute has so far developed several high yielding and disease resistance lines that are being used as commercial varieties as well as germplasm. The institute is therefore, contributing extensively in enrichment of cotton germplasm, an important component of varietal production.

Wild relatives of chickpea and barley are also being used for improvement of disease resistance of the respective crops (ICARDA, 1996) and is thus, contributing significantly towards conserving the wild genes into commercial cultivars to be utilized in future programmes. In all these examples, genetic diversity native to the local land has been conserved through the use of local expertise and knowledge. In the future world of corporate agriculture, this would be the only option for developing countries to secure their resources and ensure food security to future generations.

What is happening to agro-biodiversity and what are the underlying causes?: Today, much of the diversity is being lost and many unique varieties are disappearing and becoming extinct. Since the beginning of the 20th century, about 75% of the genetic diversity of agricultural crops has been lost due to tropical deforestation, urbanization, destruction of wetland and cultivation of dry-lands that has destroyed the habitats of many wild progenitors of domestic crops (FAO, 1993a). Deforestation, use of land resources and poor quality of irrigation water destroyed the valuable genetic reserves of wheat and its wild relatives in the Near East (Ponting, 1991). Till 1949, China had been using nearly 10,000 varieties of wheat, which by 1970 were reduced to 1,000 only. Statistics from China indicated that by 1950, local varieties accounted for 81% of production, locally produced varieties made up 15% and introduced varieties only 4%. By 1970, the figures had changed drastically; locally produced improved varieties accounted for 91% of production, introduced varieties remained 4% while local varieties decreased from 81 to 5% (FAO, 1996e). A survey of farm households in the Republic of Korea showed that of the 14 crops cultivated in home gardens till 1985, only 26% were left till 1993 (FAO, 1996f; FAO, 1998). The retention rate did not exceed 50% for any crop and for two crops it was zero. These results are disturbing because m such home gardens have traditionally been important conservation sites, especially for vegetable crops (FAO, 1984). Mexico is currently using only 20% of the maize varieties used earlier in 1930 while the remaining 80% have probably been eroded (FAO, 1996a). If the genetic erosion which refers to a loss of individual gene, gene complexes and/or loss of a variety (FAO, 1994), is not strictly stopped, some 60,000 plant species which is about 25% of the world existing plant species could be lost by the year 2025 (ICARDA, 1996). Assuring food security under such circumstances would partly depend on finding ways to conserve areas rich in crop plant diversity as well as on expending germplasm production and collection (World Bank, 1996) especially in the areas where biodiversity is extremely threatened.

The most important reason for the loss of genetic diversity is the replacement of traditional varieties with green revolution varieties, which, by 1990 covered 115 million hectares. Decline in agriculture bio-diversity is also threatening wild relatives that are the only hope in time of crises especially for the people living in the marginal areas. Not only the locally diverse food production systems but their accompanying local knowledge, culture and skills is also disappearing. Some of the other reasons are rapid expansion of industrial agriculture, increasing population and greater competition for natural resources. Extensive livestock production, globalization of food and marketing, industrial patenting and intellectual property systems to living organisms also played significant role in reducing genetic diversity. Cultivation of fewer varieties and breeds, far less diverse but more uniform and competitive global market, also resulted in margenalization of farmers' varieties and breeds of domestic animals: the genetic pool for food and agriculture in the future.

With decline in agro-biodiversity, harvested and non-harvested species and varieties are also vanishing. Till to date, about 90% of crop varieties have disappeared and half of the breed of domestic animals lost. Chronic over-fishing and mismanagement virtually wiped out one of the world's most productive fisheries: the four million tons of cod on Canada's Grand Bank. Canadian government closed this fishery altogether and thousands of fisherman lost their jobs. In all of the world major fishing areas, the fish catch has dropped by more than 30% (FAO, 1995a,b).

In poor countries particularly and also elsewhere, limiting such natural resources due to bad management and agricultural practices will make it difficult to meet food needs both now and in future (Brown, 1997; Gardner, 1996; Lincoln, 1993). Food security over the long term will depend on making agriculture production environmentally sustainable, which means that it will conserve land, water and plant and animal genetic resources, will not allow degradation of environment and will be economically viable and socially acceptable (FAO, 1996c). Sustainable agriculture is therefore, the need of day to ensure food security of the future generations.

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