

## Workshop Discussions

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The first day of the workshop dealt with the physical environment and farming systems in the five broad mountain regions of the world, namely, Hindu Kush-Himalaya(including Xizang), Andes, tropical African mountains, north African and mid-eastern mountains. The seven papers presented during the day amply demonstrated that it is necessary not only to consider the geomorphologic and meteorological factors at the macro scale in determining agricultural diversity, but also the micro level differences in altitude, aspects, locations, soil types, and other socio-economic aspects such as accessibility(trade and marketing) and opportunities for migration, transhumance and shifting cultivation. The salient issues raised during the presentations of the papers and the ensuing discussions are highlighted below.

### A. Physical Environment and Mountain Farming Systems

#### a) Hindu Kush-Himalaya Region

The extreme diversity in the climate, flora and fauna prevailing in the Hindu Kush-Himalaya region was the topic of discussion and deliberation. The main theme was that the great diversity in the micro and the macro climates in the mountains emanates from the geomorphological diversity (Maharjan et al). Furthermore, it was noted that the genetic diversity and vegetational change are influenced by diversity in the soils and the climate. The main determinants of the farming systems are indicated to be the variables of the climatic, vegetational and soil categories. The conclusion was that the agro-ecological zones provide a suitable means of identifying physical determinants of the farming systems' diversity.

The complexity of climate, vegetation, and human activities, particularly the complexity represented by the farming system, and the agroecological zones within the Hindu Kush-Himalaya region, was stressed. The broad relationships existing between the climate and the vegetation were described in an impressionistic manner. In the central Himalaya, for example, three distinct farming systems are noted, namely, terai farming systems, middle mountain farming systems, and high mountain farming systems. As expected, due to the warm climate, the terai farming systems are characterized by the dominance of cropping activities, particularly , paddy cultivation. The middle

mountain farming systems, on the other hand, are predominantly crop cultivation based, and the temperate climate and high elevations result in the prominence of maize over other crops. The importance of animal husbandry activities also tend to increase with the elevation. In contrast, high mountain farming systems are primarily livestock sector based. There are frequently, transhumance activities associated with this system; a single crop of barley, wheat or millet is also grown. During the discussion, however, it was noted that heterogeneity often implies that these generalisations constitute as much a rule as an exception. An important source of the farming systems' diversity lies in the microlevel climatic differences emanating from changes in the aspect (north or south facing slopes) and the orientation of a specific farm plot.

The diversity prevailing in the socio-economic domain was also presented, although the main attempt was to deal with the classification of the farming systems' diversity, commensurate with a set of agroecological zones. The latter has to be consistent with climatic zones and associated human interactions with the biotic natural resources of the various botanical and/or crop zones (related to climatic and ecological zones).

The problem of classification of the diverse farming systems, in the context of mountain development, indicated that the popular classification approaches have tended to be biased on account of a single differentiating factor, such as, geography, geomorphology, climate, botany, soil types and crops. It was noted that such single factor approaches are bound to gloss over the anomalies as microscopic irregularities which require other discriminating factors to explain the anomalies. Botanical classifications based upon crops or forest vegetation were shown to be unsatisfactory because forests tend to degenerate badly and most of the crops grown have great cultural affinity (so that they do not entirely capture or represent the agro-ecological factors). A classification suitable for conservation, the exchange of genetic resources, and for planned mountain development, must be based on an approach which can simultaneously deal with the critical elements of the agro-ecological zones and the farming systems (such as, climate, soils, botany, and farming practices).

Similarly, in dealing with the agricultural system of the Tibetan mountain regions, it was shown that the three main types of the farming systems were prevalent in Tibet (Cheng Hong). These systems can be presented in terms of the relationships between animal husbandry and crop cultivation activities. The first category can be represented by the pastoral system, where the major farming activities consist of animal husbandry. The pastoral-farming system consists of nearly equal levels of cropping and animal husbandry activities.

The agricultural system, the next category, is found in the lower valley regions where adequate sources of water to grow maize, wheat, barley and buckwheat exist. The animal husbandry system, prevalent in the north, west and high elevation south Xizang, have very little or no cultivation due to severe cold conditions, and depend solely on animal husbandry production for subsistence. The transitional Pastoral farming systems exist at the periphery of the agricultural areas, with dominant animal husbandry/livestock activities mixed with marginal crop cultivation. The agricultural system, in the valleys of the five large and small rivers of Yarlungzabu jiang, Lhasha he, Nyan Qu and Parlunzabu, grows cereals such as, wheat, rice, maize, barley and naked barley. The pastoral farming and agricultural systems may be further divided into three categories, namely, spring sowing single crop system, spring-winter sowing single crop system and the double crop system. The latter is possible only in the deep dissected river valleys of south east Xizang with a warm to hot climate and good water availability.

The farming systems of the middle and high mountain regions of Nepal are dominated by Hill Farming Systems, which are limited to river valleys and terraced slopes, with *khet* and *bari* lands (Pant and Gautam). It is based upon subsistence crop agriculture, and is characterised by intensive land utilization and a heavy dependence on livestock and forest inputs. Livestock plays a crucial and decisive role in the hill farming system, as it is responsible for the transfer of nutrients from forests and pastures to farm lands. It was, however, noted that increasing livestock numbers is causing the fodder deficit. Overgrazing and fodder lopping have contributed to soil erosion and landslides. Maize is the dominant crop in the system, followed by rice, wheat and millet. In the *bari* land, popular cropping patterns are maize based along with finger millet as a relay crop. Mustard, potato and black gram are also grown, whereas soyabeans are often intercropped with maize. Because of wide micro-climatic variations, a high potential was noted for horticultural development within these systems, for both tropical and temperate fruits.

The Mountain Farming Systems, due to higher elevations and adverse climate, are primarily livestock oriented, with cropping depending entirely on livestock manure. Cultivation is limited to the lower slopes and the relatively fertile patches of narrow valley floor (along the rivers). The dominant crop is maize followed by wheat and rice, with rice/maize-wheat and buckwheat-naked barley cropping patterns respectively on the lower and higher elevations. Potatoes are grown at still higher elevations. The agro-climate of the mountains is very conducive to temperate fruits, such as apple, peach, plum, apricot. Great potential exists in fruit development for making whisky and concentrated juices in these areas, keeping in view the transportation hurdles. Potential for vegetables is also notable in these areas, particularly for seed production.



Therefore, it was concluded that for the improvement of hill agriculture, it is necessary to develop hill crops, livestock, horticulture and agro-forestry within a systems perspective. Improvement of input delivery systems, marketing and the use of integrated farming system research is needed.

## b) The Andean Mountain Region

The environment, demography, social organization of production and the farming systems of the Andes are similar yet distinct with respect to that of Hindu Kush-Himalaya region. A case study of a peasant farming community of Amaru Cusco (Peru) was very informative. The rich and complex adoption and selection of crops and animals was shown to result from the particular climate, orography and the soil of the high Andes (Mateo and Tapia). The major agro-ecological zones, namely, *west inter-andean valley (yunga alta)*, *quechua*, *puna*, *suní highland*, *lakeshores and eastern slopes*, traverse the Andes from west to east. These also correspond to the *homogeneous zones of productions* that was presented. Animal husbandry is important in high altitude zones, such as, *puna*, *suní* and the lakeshores, as in the case of Hindu Kush-Himalaya. The *suní* highland areas grow barley, quinoa, kaniwa and tubers of various kinds. The *puna* highland zones grow bitter potato species (*S. juzepzukii*, *S. curtilobum*) along with barley, kaniwa and tubers. Maize is a very important crop in the lower altitude *quechua* zone, although potato, barley and fafa beans, peas, and terwi are also grown. The *west valley* agro-ecological zone has maize, fafa beans, and fruits, as important products, along with potato, quinoa and tubers. It may be noted that animal husbandry systems in *puna* and *suní* zones are, respectively, based on *alpaca* and *llama*. The latter is important also in *quechua*, and *eastern slope* zones. Ruminants and goats are predominant in *west valley*, *quechua*, *suní* and *lakeshore* agro-ecological zones.

The special characteristics which are responsible for the evolution and sustenance of mountain agriculture and the large population of the Andes were indicated to be **domestication of crops and animal species, food conservation and storage systems, transportation and accounting systems**. The use of *quolqas* (large stone silos), for grain storage and the accounting system based on *Kipu* (knots) date back to the Inca period. The paper notes the edaphic conditions and the characteristics of indigenous soil classification systems, indicated above. The presentation also included the three main *homogeneous zones of production (HZIP)* for Cusco, Peru. The maize, potato-cereal-legumes, potato-muyuys-range HZIP's, respectively, were found at lower (3500 masl), middle (3600-3800 masl) and high (above 3800 masl) altitudes.

During the discussion it was pointed out that the demographic factors (migration) affecting the nature of the farming system, particularly

with respect to other crops apart from maize and potato in the Andes, was not clearly understood. It was indicated that the increasing population pressure in the Andes has induced a significant degree of crop diversification. The other important crops grown are naked barley, wheat, oats, beans and lupines. Horticultural crops are not as well developed on account of the constraints of accessibility and markets. It was further added that, ruminants, hogs, and horses have been imported from the new world into the livestock sector. The replenishment of soil nutrient in the farming system was indicated to be a significant degree of animal manure applied in the fields in the Himalayas and the Andes. The use of fertilizer is, however, low on account of the high cost of fertilizer transport. The subsidy required is provided in some countries through low interest credits to buy modern inputs.

An important question emerged at this stage about the potential and feasibility of exchanging germplasm between the Andes and Himalaya, which are similar in many respects. It was stressed that action on this aspect is apparently still lacking, despite the realization of good potential and feasibility.

The discussion then moved towards the effect of accessibility, transport and other marketing services which change and affect the very structure of subsistence farming activities, moving more towards commercialised agriculture (with cereal cropping activities being substituted by horticulture and livestock activities). It was suggested that it is very important to examine and understand the role of livestock/animals within the farming system. The bias, which has emphasized crops so far, is being corrected in farming systems research in many countries. The homogeneous zones of production and the various factors/criteria which may be used in delineating these zones were discussed. It was noted that meteorological data and climatic aspects alone could not be used in the zonal classification. The indigenous names, such as, "puna" do describe relatively homogeneous production zones, which already take into account a diverse set of factors well known to the local inhabitants, such as, quality of soils, moisture and the established (feasible) production activity. It was further emphasized that micro-ecological factors, such as aspect and orientation, heavily influenced the type of crops that can be grown in an area.

#### c) West Asia, North and Tropical African Mountain Regions

The diverse mountain environments and the farming systems found there *describe tropical African mountain environments and their farming systems* in some twenty African countries (Ethiopia, Uganda, Tanzania, Rwanda, Burundi, Kenya, E.Zaire, and the islands of Madagascar and Reunion are notable for mountain environments) and therefore,



represent an equal or greater degree of diversity in climate and botany as compared to the Andes or the Himalaya. The heterogeneity of tropical mountain environments also result in diverse farming systems in the African setting. The farming systems in these areas are largely dominated by rainfed mixed agriculture. These farming systems may be further divided into two broad types, namely, the **equatorial mountains/high lands** and the **sub-tropical mountains/high land farming systems** (Getahun and Kirby). The first type of farming system is characterized by an intensive agricultural system based on horticulture, integrated with root/tuber crops and vegetables. The livestock sector is fairly important in this system for manure, as in the case of the Hindu Kush-Himalaya or the Andean region. Cultivation is done entirely by the hoe and cash crops such as tea, coffee, pyrethrum, *chat* are common.

The second type of farming system is dominated by cereal crops and utilizes plough agriculture. The major crops include cereals (wheat, maize, paddy), pulses and oil seeds. Animal husbandry is also important in this system. The highlands, lying between the first and second types of farming systems, show a transition between these two systems. For example, the eastern highlands of Ethiopia show both intensive and extensive farming systems, with a mixture of cereal and horticulture crops being cultivated. The diversity of food and cash crops is particularly high in the Ethiopian and the Arusha-Kilimanjaro region (Tanzania). There are about 169 types of crops grown in the Harar highlands (Eastern Ethiopia) and about 111 types in Arusha-Kilimanjaro region, many of which are cereals, oil crops, fruits, beverage crops, fibre crops, grain legumes, vegetables, bulbous roots, tubers, condiments and drug (medicinal) plants. Some of these crops are rare and are nationally and regionally important, for example, *tef* (*Eragrostis abyssinica*), *Lathyrus*, *Guizotia abyssinica*, *Ensete ventricosum*, *Colcus edulis*, *Coccinia abyssinica*, *Catha edulis* and *Carthamus tinctorius*.

Mr. Potts presented his paper on *mountain physical environment and farming systems in west Asia and north Africa*. The environments of the west Asian and the north African mountains are also very complex although they are quite dry compared to the monsoon-dominated Himalayas. The presentation focused on details from the representative environment and the farming system of the Yemen Arab Republic. The tropical highland climate with an arid to semi-arid moisture pattern, and a bimodal rainfall regime, give rise to four main types of farming systems in this region. The **rainfed cropping system** is mainly based upon cereals (wheat, barley) along with legumes (cowpea, lentils) intercropped with sorghum. The **irrigated cropping system** grows maize, wheat, sorghum, along with vegetables and alfalfa. The **irrigated orchards** grow coffee, *kat* (*Catha edulis*), grapes and banana. The **grazing system**, utilizing the tribal grazing rights, consists of cattle, sheep, goats, donkeys and camels (Potts). It was stressed that recent changes in opportunities for jobs in the adjacent oil-exporting countries

have resulted in a large out-migration. This has undermined the majority of the farming systems in these mountain areas.

The discussion started with issues related to the recent trade imbalance in many countries of the region, such as, Yemen. It was indicated that, due to a large amount of the food being imported in the middle-eastern countries (which has had adverse effects on the agricultural sector), food security has become an important issue in these areas. It was thought that due to the oil boom in the middle-east, migration away from farms has become a serious problem; marginal fields are being abandoned in many areas. It was further suggested that the demand for livestock products has induced growth in animal husbandry activities and created over-grazing and erosion in many mid-eastern mountain areas.

However, due to falling oil prices, it is now seen that off-farm employment opportunities in many of the middle-east countries are also declining. The adverse effects on the hill areas have come about because of reduced employment opportunities outside and those farmers coming back to these hills find fewer alternatives. The increased pressure on these areas and the decline in the general fertility and productivity indicates the nature of the problems these areas face when exogenous factors change. These changes have, generally, tended to enhance genetic erosion in these mountains. In this context it is important to consider the approaches that can be used to identify and design sustainable development initiatives. Specific instances of the diagnostic survey used for physical infrastructure development, the agro-ecosystems analysis used for village development, the forestry rapid appraisal and the farming systems survey carried out for farmers in the AKRSP area of Pakistan were also discussed (Hussain). These techniques have been useful in identifying critical problem areas, village level priorities (for feasibility analysis), establishing an outline agenda for (prioritisation of) research and planning, and in making recommendations for village-level action-plans. The discussion further concluded that understanding of mountain environments required the researchers (and government/donors) to be able to learn about the hill farmers and their perspectives on their mountain environment. The process of learning was regarded to be of great importance in the context of preventing genetic erosion in the mountains.

## **B. Genetic Resources of Mountain Crops**

The second day of the workshop was devoted to the genetic resources of mountain crops. The ten papers presented during the day focused upon the genetic resources of cereals, fruits, root and tuber crops from the Andean mountains, the Himalaya region, the Tibetan plateau, and the northern hills of Thailand. A couple of papers focused upon the diversity of genetic resources in general, for example, the paper on Thailand by Chantaboon



Sutthi and the paper on phylogenetic and zoogenetic resources of the Andes by Tapia and Mateo. Other papers concentrated upon the exchange of crop genetic resources carried out by the National Bureau of Plant Genetic Resources, New Delhi, India.

Two distinct and separate approaches to the categorization of plants were discernible during the presentation. The standard approach of classifying crops in terms of cereals, fruits, root and tuber crops, may be contrasted with the classification through end-use of these crops. For example, mountain and upland agriculture and genetic resources in Thailand have been described by Chantaboon Sutthi using the latter approach. He provided a detailed account of the farming systems and a detailed inventory of cultivated plants. The plants have been categorized in terms of *swidden* (shifting cultivation) and *non-swidden* crops. They are examined in terms of (a) primary, (b) secondary, and (c) socio-economic and medicinal use categories. The primary use is further divided into types of use, such as, staple food, vegetable, root-tuber-rhizome and animal food. The secondary use category consists of sub-categories: food and snacks, fibre and utensil and others. The last category has further sub-categories: religious & ceremonial, decoration & cosmetic, cash, medicinal etc. The classification of crops by other contributors was by traditional categories: cereals, fruits, tubers etc. However, it should be noted that King and Vletmeyer, Mateo and Tapia, find a great advantage in looking at these categories in the context of local indigenous names. The latter throw a considerable light on the place of these plants/crops in agro-ecological zones (so called homogeneous zones of production).

The traditional categorization (in terms of cereals, fruits etc.) are adequate to describe the components of the agricultural farming systems; however, they are not suitable for looking at change in crops grown and the factors influencing that change. The division of crops according to their uses provides various advantages. For example, the use categorization provides a useful means of identifying the various processes of change in the cultivation of diverse crops and plants.

It should be noted that a number of factors are responsible for the adoption of newer crops in the mountains and often the same factors are responsible for the abandonment of older, traditional crops or varieties. For example, the agricultural systems in Thailand are seeing a drastic change over the past decades, on account of economic and commercial factors and due to developmental interventions (Chantaboon Sutthi). Similar changes were indicated in other parts of the Himalaya region (Anwar and Bhatti, Tej Pratap, Bhattarai et al) as well as the Andean region (Tapia and Mateo, King and Vletmeyer, Tola et al).

The rate of genetic erosion in some areas is alarming and is found to be high in most of the mountain regions of the Hindu Kush-Himalaya, the Andes, and the African mountains. The need for deliberate intervention on the part of researchers and other scientists is a matter of considerable



urgency if the genetic diversity of the mountainous agricultural systems is to be preserved, in the face of increasing vulnerability to low land market economic forces and the threat of over-specialization in crop cultivation (Chantaboon Sutthi; Tola et al, King and Vietmeyer). It may be further added that genetic erosion should be checked as far as possible through various ways of crop rehabilitation and reorientation of crop extension activities. The germ plasm collection, distribution and exchange, along with species research, are vital to achieve these goals.

Extensive deliberations concentrated upon the nature and diversity of the genetic resources present in these mountain regions within each type of the crop. Amongst the various uncommon crop species considered, a significant amount of time was spent during discussion upon the potential and prospects for cereals such as *chenopodium*, finger millet, arid and naked barley, upland paddy, maize. Tubers and beans were also dealt with, although the latter was not intensively deliberated upon. The discussions also focused upon the prospects for exchange of germplasm between Andean, Himalayan and African regions and the need to set up networks and institutional links between and among the countries of the region, at the national and the regional level, especially for the exchange and conservation of germplasm.

The genetic diversity existing in the mountains, and the continuing genetic erosion may be dealt with in terms of the following categories of crops;

- a) Cereals (both conventional and non-conventional indigenous species)
- b) Tubers and Root Crops, and
- c) Fruits and Medicinal Plants

Occasionally, the discussion also took on beans and fodder crops, although deliberations on these did not take up enough time to warrant separate treatment. The importance of this type of crop was, however, realised and fodder was included in the Crop Exchange Table prepared during the final day of discussion and recommendation.

#### **a) Cereal Crops**

The crop genetic variability of various cereal plants, particularly the common species such as paddy, wheat, maize, barley, and finger millet, is indicated to be quite high in the Hindu Kush-Himalaya region, as well as in the Andean and African mountain regions. The adoption of high yielding varieties of these crops has again caused a considerable rate of genetic erosion of various land species.

The various cereal/crop genetic resource activities undertaken in various parts of the mountain areas are exploration, conservation, characterization and utilization (or breeding). In many mountainous

countries and regions the absence of significant achievements in conservation and utilization of various land species has been caused by lack of long-term priority given to germplasm activities, lack of skilled manpower in research and low budgetary allocations, inadequate even for well established germplasm research activities. Bhattarai et al have indicated this to be the case in Nepal, for example, and a similar situation prevails in Bhutan, Pakistan and some African countries.

In the Hindu Kush-Himalayan region, various cereal crops have been collected and analyzed, although conservation and utilization in breeding have not been entirely successful. For example, in the Nepal Himalaya, some collection and analysis of rice, maize, wheat, barley and finger millet have been carried out. Similarly, the wheat and rice varieties of Pakistan are observed to be quite considerable (Anwar and Bhatti). In Pakistan the wheat species collected and analyzed include *Triticum aestivum*, *T. Durum*, *T. turgidum* and *T. polonicum*. The rice varieties collected from Baluchistan belong to the species *oryza sativa*. The immense climatic, topographical and edaphic variations reflect corresponding changes in the developmental characteristics of these crops. *T. aestivum* populations display differences in awning, pubescence, straw thickness and other traits. Similarly, diversity in several genetic and agro-morphological traits as observed in indigenous rice varieties. Some wheat varieties (*Triticum sphaerococum*) were found to be highly drought resistant.

In the Indian Himalaya, the role of the National Bureau of Plant and Genetic Resources (NBPGR) in India, has been quite considerable in exploration, characterization and exchange of crop genetic resources (Joshi and Paroda). Activities included the collection of 10,000 samples of wheat, maize, amaranth, buckwheat, cheropod, millet, mustard, beans and peas, from many parts of India, between 1980-1986, from Jammu and Kashmir to Tripura and Assam. These germplasms were evaluated for various agro-morphological characteristics and important donors and elite lines were identified and multiplied for distribution (more than 33,000) to crop improvement programmes, user agencies and international research institutions.

Similarly, the pattern of variability of important high land crops, such as millet (*Elenisne Coracana (L) Gaertn*) with altitude has been studied in detail. The structure of yields has been evaluated on the basis of phenotypic characteristics (Mann). The eighteen varieties tested at three elevations indicated a heterogeneous pattern of adaptability. For example, the total grain bearing area has a direct relationship with yield. Analysis indicates that the influence of the environment tended to differ considerably from one to the other. The yield contributing factors tended to possess average adaptability at high altitude mountain conditions and thus provides a good basis for using these cultivars in breeding programmes to improve yields.

The introduction of modern varieties of the crops has generally tended to displace many native crops and cereals. The conservation and development of these native crops, such as *amaranth*, *quinoa*, *chocho* (*Lupinus mutabilis*), and tubers, such as Oca (*Oxalis tuberosum*), melloco (*Ollucus tuberosum*) have been emphasized repeatedly. It has been indicated that although the cultivation of Chenopod declined recently, it is still being cultivated in many parts of the Himalayan range, such as, Jammu and Kashmir, Himachal Pradesh, Utrakhand, Sikkim, the Khasi Hills of India, in Nepal and parts of China (Tej Pratap). The nutritive value of these grains is high, as they contain 16% protein, 7% fat and nearly all the amino acids in appreciable quantities. This crop is very suitable for mountain agriculture on account of its adaptability to mixed farming, relatively short phenological calendar and ability for easy germination and establishment. However, the crop may face extinction if it is scientifically neglected and not developed to its highest potential.

After the examination of the status of valuable native Andean crops in the mountains of Ecuador, it was indicated that, despite being a major centre of plant genetic diversity within the Andean region, Ecuador has depended on only a few species for domestic consumption and export, such as, maize, potato, barley, wheat, beans and fafa beans (Tola et al). Native Andean grains such as quinoa (*Chenopodium sp*), chocho (*Lupinus mutabilis*), amaranto (*Amaranthus sp*) and tubers, such as, melloco (*Ollucus tuberosum*), oca (*Oxalis tuberosum*) have been relegated to a minor position, despite their potentially high utility in mountain regions. However, these species are still predominant in the fields of poor farmers. The recent progress made in germplasm collection, farm trails and culinary demonstrations of quinoa in Ecuador indicates that other Andean crops may be similarly promoted in other mountain regions.

In the context of the overall Andean region, the crops and animal resources indicate a rich diversity and a tremendous potential for future collection, development and extension. (Tapia and Mateo). Furthermore, the evolution of the farming system in the Andes represents a high degree of integration of cereals, root crops and tubers with the unique Andean camelid. The grain crops discussed were Quinoa, Kaniwa, Kiwicha, Tarwi, along with tubers, Oca, Olluco and Mashua. The root crops considered were Maca, Jimaca, Ajipa, Arracacha, Yacan (*Jiquima*) along with native fruits, Chirimoya, Pacae, Huagra-manzana, Tumbo, Capuli, Lucuma etc. The South American camelid, such as, Llama, Alpaca, Vicuna, Huanaco, and domesticated birds (poultry) and rodents have potential for further promotion in various mountain environments. The present efforts devoted to collection and establishment of crops and animal germplasm banks have been indicated along with the responsible institutions.



In the Himalayan region, which is far from being a unique case, the comparative study of wild and domesticated barley has thrown considerable light on the potential for genetic improvements in various crops (Shao, Zhou and Li). The genetic unity of wild and cultivated barley has been demonstrated after a comparative analysis of different species of wild and cultivated barley from the northern and the southern slopes of the Himalaya. The morphological, cytological, genetic and ecological analysis supports the thesis of genetic unity within the wild and domesticated varieties. This has provided a better understanding of the process of barley evolution and has tremendous practical importance because wild barley, which is highly disease resistant, provides the original material for disease resistant breeding. It was emphasized that similar possibilities exist with respect to other crops such as rice, wheat and maize, with tremendous potential benefit to all mankind.

## b) Tuber and Root Crops

The evaluation of Andean root and tuber crops indicated the potential for exploitation of at least nine major root and tuber crops from the high lands of South America to the Himalayan and African mountain regions (King and Vietmeyer). The presentation focused on the distribution, habitats, cultivation, utilization, nutritional value of maca (*Lepidium meyenii*), ulluco (*Ullucus tuberosus*), Oca (*Oxalis tuberosa*), Anu (*Tropaeolum tuberosum*), Arracacha (*Arracacia xanthorrhiza*), Achira (*Canna edulis*), Mauka (*Mirabilis expansa*), Ajipa or Jicama (*Pachyrhizus tuberosus*), and Yacon or chicama (*Polymnia sonchifolia*). The sources of seeds, germplasm and information for the crops were indicated. The need for basic and applied research on diseases, pests and post-harvest processing techniques of these crops was emphasized so that they could be transferred to other eco-geographic zones. The establishment of a coordinated network of international crop exchange should be promoted between countries with mountain environments to facilitate the diffusion and exploitation of these valuable crop genetic resources.

The tubers and root crops specifically from the Hindu Kush- Himalaya and the African mountain regions were not highlighted, although it was indicated that a diverse set of potatoes and yams were available in these areas also. In the high altitude areas in the Himalayas it was reported that potato cultivation provides an important contribution to the food supply and therefore, there was a need to develop a disease and drought resistant potato (*Solanum sp.*) crop suitable for these high altitude areas, which are prone to frost. It was also indicated that some species of potato from the Andes have leaves with a sticky substance on them which glues small insects (*nematodes*) to the leaves. Such genetic characteristics are desirable and may be bred into other potato species which would then be able to control insect attacks.

### c) Fruits and Medicinal Plants

In dealing with the crop genetic resources of Nepalese mountains, it has been pointed out that there exists a good store of tropical and temperate fruits and valuable medicinal plants in various agro-climatic niches in the Himalayas (Bhattarai et al). Amongst the medicinal plants, *Digitalis*, *Atropa belladonna*, *Chrysanthemum*, *Ceneriaefolium* are grown in the temperate zone herbal farms. The subtropical medicinal plants grown are *Rauwolfia serpentina*, *Cympopogon winterianus*, *C. martinii*, *Mentha ariensis* and *Dioscoria floribunda*. The various activities undertaken in Nepal are exploration, conservation, characterization of fruits and medicinal plants. It was, however, noted that development of species for extension and domestic cultivation has been limited on account of various financial and accessibility constraints in Nepal and Bhutan Himalayan regions.

The discussion on activities related to the fruit genetic resources of the mountains of Pakistan (Bhatti and Anwar) and India (Joshi and Paroda) concentrated on the collection and conservation of various fruit germplasms for peach, apricot, plum, almond, cherry, apple, grapes, walnut, pear, pomegranate, quince, mulberry and fig. The species samples collected by PARC in Pakistan (NWFP and Baluchistan) were 96,227,137 respectively for the years 1982,1983, and 1986. These are maintained in clonal repositories. The cutting of fruit trees for firewood and the distribution of grafted fruit seedlings pose a severe threat to indigenous fruit varieties and cause genetic erosion.

Similarly, germplasms in India are maintained on various types of fruits at NBPGR and at various horticulture stations in the states of Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir.

In view of the great potential contribution which fruit, vegetable and fodder trees can make towards the growth of mountain economy, elements of future strategies were outlined. These elements consist of collection of local germplasm, introduction of high value crops, establishment of mountain crop research systems, farming system research and international cooperation in the exchange of information and germplasm through exchange visits and seminars (Bhattarai et al).

A lively discussion ensued on the tolerance of toxins in amaranthus, chenopodium and quinoa. It was pointed out that several washings were adequate for the removal of these toxins for human consumption. The discussion then moved to issues of germplasm exchange: lupins were commercially cultivated in Ethiopia and Kenya, along with the introduction of tree tomatoes and passiflora during the sixties and the regular exchange of plants occurred between Ethiopia and Ecuador. The differences in altitudinal and geographic cropping limits (due to temperature and rainfall) between the Andes and the Himalaya were pointed out. The need for agro-ecological zonations for both the regions



was indicated so that source and target areas for crop exchange could be demarcated. These conclusions were further elaborated during discussion on the final day of the workshop and the Crop Exchange Table worked out as shown in the following section.