jected to SSCP by PAGE. The recognition of shift in the migration of strands was thus made easy. Another factor, that is the multiple conformations of strands would also limit the efficiency of PCR–SSCP analysis. The SSCP analysis of the PCR products of all our samples produced 4 bands in a different gel format and protocol (data not shown). This could be attributed to the possible two conformations of each of the strands while the other possibilities cannot be ruled out. Similarly, Telenti *et al.*[8] observed a three-band pattern in his samples. In the present study, the occurrence of the multiple conformations of strands was not observed although it remains to be explained.

A large-scale study to determine the association of the migration pattern of single stranded DNA with the specific nucleotide change in the *rpoB* gene might be useful for the presumptive identification of specific mutants in the clinical isolates. It is interesting to note that Telenti *et al.*[9] observed a specific migration pattern for each of the nucleotide substitution.

In this study, 3 (nos 6, 20, 21) of 6 rifampicin-sensitive strains were misclassified by the PCR–SSCP. It should be realized that SSCP does not differentiate rifampicin-sensitive strains with functionally silent sequence changes. Therefore, DNA sequencing of the PCR products only could confirm the mutations occurring in these 3 specimens. Also, 1 (no. 4) of 15 rifampicin-resistant strains was misclassified by PCR–SSCP in the present study. On scrutiny, this isolate was obtained from a patient whose alternative isolates were sensitive to rifampicin. It should be pointed out that using different protocols such as conventional PCR–SSCP[8] and automated sequencing[10], the variations in the classification were reported. In the former, 2 of 66 and in the latter 3 of 121 rifampicin-resistant strains were misclassified.

The present PCR–SSCP format takes less time and is less expensive as it involves only one PCR. The results suggest that this procedure can be adopted for the detection of mutations in the *rpoB* region of *M. tuberculosis*. However, a separate study using a large number of sensitive and resistant strains needs to be carried out to assess the validity of the method. Also, attempts should be made for the early detection of rifampicin-resistant *M. tuberculosis* in sputum samples of pulmonary tuberculosis patients as it is a surrogate marker of multidrug-resistant tuberculosis.

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Eroding traditional crop diversity imperils the sustainability of agricultural systems in Central Himalaya

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The subsistence agricultural systems of the Central Himalaya harbour a huge variety of traditional crops and cultivars. However, a recent survey conducted in 150 different villages located along an elevational transect of Alaknanda catchment of Central Himalaya reveals that over a period of two decades (1970–74 and 1990–94) the cultivated area under many traditional crops has declined precariously due to various reasons. Many crops are facing danger of complete extinction and consequently the ecological and economic security of the traditional farming systems of this region appears to be in jeopardy. Linking traditional crops with economic development of hill farmers through value addition adopting the traditional and modern appropriate technologies may be the suitable strategy to conserve these crops *in-situ*.

MODERN agriculture, undoubtedly, has made significant contribution in minimizing the problem of hunger in the wake of ever-increasing demand for food world over. Its potentialities to fight hunger in future too, cannot be denied. For a country like India, 'food power' is a major economic power and this was partly made possible by modern agricultural technology. Coexisting with this positive aspect are quite a few negative aspects of modern agriculture such as its dependence on fossil fuel-based yield increasing inputs, risks of vulnerability in the face of unpredictable climate changes and pest/disease outbreaks, creation of nutrient imbalance resulting in soil and water pollution, loss of genetic resources and enhancement of inequity. Traditional agriculture suffered a major set back amidst a high cry of modern agriculture but still provides 20% of the world food supply[1]. Traditional agricultural systems are the reservoirs of a huge variety of crops and cultivars, many of which are still lesser known to the mainstream societies, and are better adapted to environmental conditions and social set-up compared to the modern agricultural systems[2–4]. Neither the modern agriculture nor the traditional agriculture seem to offer perfect solutions to the present complex of problems when one envisages parallel development in environmental, economic and social spheres.

Traditional farming in the central Himalaya is complex in that crop husbandry, animal husbandry and forests constitute interlinked production systems. Inaccessibility, environmental heterogeneity and ecological fragility favoured evolution of subsistence production systems sustained with organic matter and nutrients derived from the forests. Modern agriculture could not penetrate for a considerably long period due to inaccessibility and extreme ecological conditions[5].

Reduction in crop diversity is one of the fast spreading recent changes in the region. The rate, causal factors and impacts of the declining trend in biodiversity are discussed in this paper.

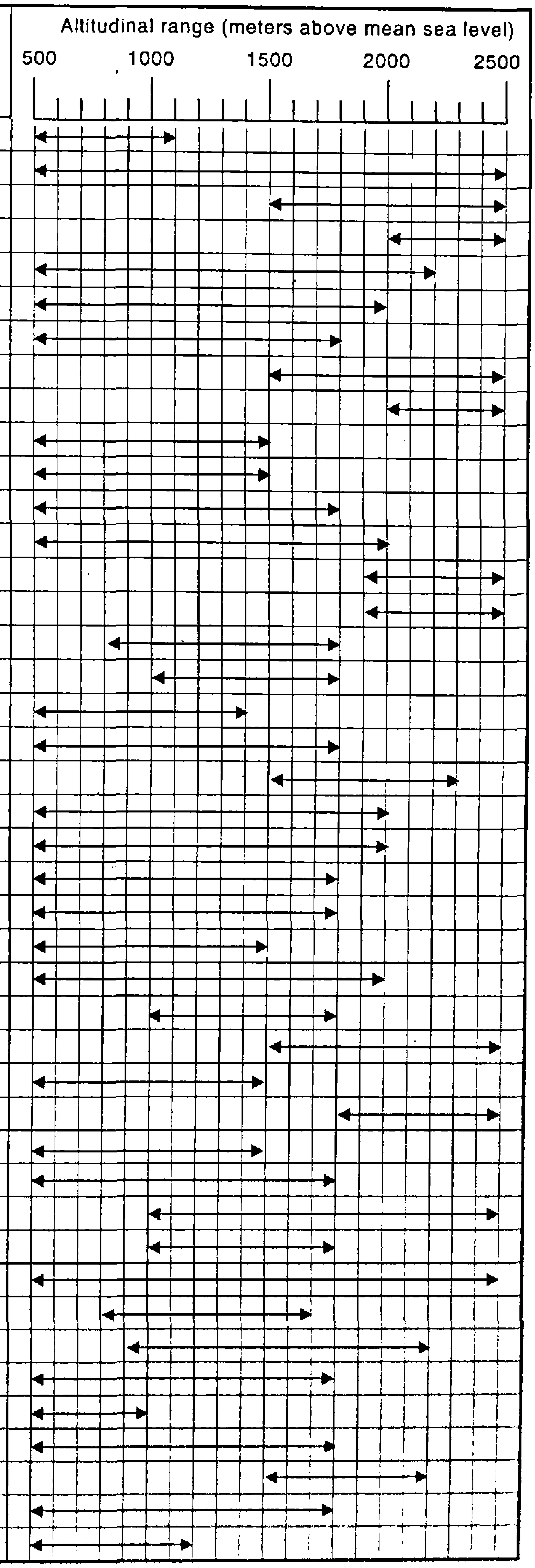
About 80% of people of Garhwal hills of Central Himalaya practise subsistence agriculture. Land holdings are small and fragmented. Per capita cultivated land is 0.2 ha. Terraced slopes, covering 85% of total agricultural land, are largely rainfed, while the valleys, covering 15% of area, are irrigated. Mixed cropping is common in rainfed agroecosystems. The cropping patterns are built around two major cropping seasons, viz. Kharif (April–October) and Rabi (October–April) generally up to 1800 m amsl and, at some locations, up to 2000 m amsl. At higher altitudes (> 2000 m amsl), only summer season crops (April–October) are raised. Over 40 crop species and numerous farmer-selected land races comprising cereals, millets, pseudocereals, pulses, oil seeds, tubers, bulbs and spices are cultivated (Table 1). This huge diversity has been maintained through a variety of crop compositions, cropping patterns and crop rotations[6–8]. A wide range of variation in edaphic, topographic and climatic conditions and selection pressures over centuries of cultivation, has resulted in an immense crop genetic diversity. The use of bullocks for draught power and humans for labour are the important inputs into the system. Crop yields are sustained with nutrient, water, energy, and organic matter inputs from the surrounding forests[6,7].

A variety of changes including loss of genetic diversity in traditional farming systems in Central Himalaya have emerged in response to population pressure, socio-cultural changes, technological innovations, market forces and land tenure/ownership policies. How much the genetic base has already eroded is hard to say, but state-driven 'Green Revolution' (i.e. supply of high-yielding varieties (HYVs), inorganic fertilizers, pesticides and irrigation free of cost initially and subsequently at a highly subsidized price) since 1970s in this region has rapidly squeezed the native landraces[5]. A recent survey of 150 villages located along an altitudinal gradient in the Alaknanda catchment of Garhwal hills reveals surprising facts on declining diversity of the traditional crops during a very short period of two decades (1974–1994). Area under oat (*Avena sativa*), buckwheat (*Fagopyrum* spp.), naked barley (*Hordeum himalayens*) and legumes like cowpea, matbean, adjuki bean (*Vigna* spp.) and horsegram (*Macrotyloma uniflorum*) declined by 72–95%. These crops are mostly replaced by cash crops like potato, soyabean, kidney bean, pigeon pea, mustard and amaranths. About 65% of the area under *Panicum miliaceum* (hog millet) and *Setaria italica* (foxtail millet) is now cropped with high-yielding rice varieties and soyabean. Cultivation of *Perilla frutescense*, *Macrotyloma uniflorum* and *Vigna* spp. is now on the verge of extinction (Table 2). Though the area under rice has not changed much, the farmer-selected cultivars grown till 1970s have been completely replaced by artificially bred HYVs of rice such as China-4, Taichung, Govinda and Saket-7. Similarly in the case of wheat, traditional varieties have been replaced by a HYV like Sonalika[5]. In the Himalayan Gazetteers of 1882, Atkinson listed 48 varieties of rice and stated that there were thousands of other nondescriptive varieties. Today only 7–8 traditional cultivars including Ramjawan, Thapachini, Lalmati, Rikhva in irrigated land and Ghyasu in rainfed areas are rarely observed[5]. Reduction in crop diversity is partly because of introduction of HYVs and partly because of increased emphasis on cultivation of traditional cash crops, a trend also observed in some other parts of the Himalayas[9,10]. When any species or cultivar is lost, the centuries old traditional knowledge about the same also disappears.

Dependency on traditional crops is more prominent in inaccessible high altitude areas compared to the low altitude ones. Food consumption ($capita^{-1} yr^{-1}$) level of the people of higher altitude villages is higher compared to the people at middle and lower altitude villages (Table 3). Around 40% of the dietary energy in the high altitude areas where HYVs of wheat and paddy have hardly reached, still comes from traditional finger millet, barnyard millet and amaranth cultivars[5].

Table 1. Agricultural crop diversity across an altitudinal gradient in Central Himalaya

Crop speceis	English name	Vernacular name
Allium cepa	Onion	Pyaz
Amaranthus oleracea	Amaranth	Chaulai
A. frumentaceus	Amaranth	Chuwa/Marcha/Ramdana
Avena sativa	Oat	Jai
Brassica compestris	Mustard	Sarson
Brassica spp	Mustard	Toriya
Cajanus cajan	Pigeon pea	Tor
Canabis sativa	Hemp	Bhang
Chenopodium album	Pig-weed	Bhetu
Cleome viscosa		Jakhiya
Colocasia himalayensis	Taro	Pindalu/Kuchain
Echinochloa frumentacea	Barnyard millet	Jhangora
Eleusine coracana	Finger millet	Koda
Fagopyrum esculentum	Buck wheat	Oggal
Fagopyrum tataricum	Buck wheat	Phaphar
Glycine soja	Soyabean	Bhatt
Glysine spp	Soyabean	Kala Bhatt
Glycine max	Soyabean	Soyabean
Hibiscus subdarifa	Roselle	Sun
Hordeum himalayens	Nacked barley	O-wa-jau
Hordeum vulgare	Barley	Jau
Lens esculenta	Lentil	Masoor
Macrotyloma uniflorum	Horsegram	Gahat
Oryza sativa	Paddy	Satti
O. sativa	Paddy	Dhan
Panicum miliaceum	Hog-millet	Cheena/Bhangna
Perilla frutescense	Perilla	Bhangjeera
Phaseolus vulgaris	Kidney bean	Razma
Pisum sativum	Pea	Matar
Pisum spp		Kong
Sesamum indicum	Sesame	Til
Setaria italica	Foxtail millet	Kauni
Solanum tuberosum	Potato	Alu
Sorghum vulgare	Pearl millet	Junyali
Triticum aestivum	Wheat	Gehun
Vigna aconitifolia	Mat bean	Bhringa
V. angularis	Adjuki bean	Rains
V. mungo	Black gram	Urad
V. radiata	Green gram	Mung
V. unguiculata	Cow pea	Sonta
V. umbellata	Rice bean	Bhotiya
Zea mays	Maize	Mungri
Zingiber officinale	Zinger	Adrak



The recent decline in agrobiodiversity is due to cumulative effect of a variety of factors including (a) degradation of the natural forests, the very base of sustaining traditional agriculture; (b) illusions about coarse and fine grains; consumption of traditional crops is considered to be a sign of backwardness in th emerging socio-cultural value system; (c) large scal migration for off-farm employment, resulting in aban donment of agricultural land; (d) supply of HYV seed at subsidized price by the government; (e) tendency fo

Table 2. Area in ha/village under different traditional crops in Kharif and Rabi seasons during 1970–74 and 1990–94 in Central Himalaya (after Maikhuri *et al.*[5])

Crops/cropping season	Area (ha/village) 1970–74	Area (ha/village) 1990–94	Area declined in percentage	Probable reasons for decline
Kharif season crops				
Panicum miliaceum	14.2	4.9	65.5	Cultivation/introduction of high yielding rice varieties (HYVs)
Oryza sativa (irrigated)*	14.2	14.2	–	Cultivation/introduction of HYVs
Avena sativa	15.8	3.4	78.5	Cultivation/introduction of potato
Fagopyrum tatatricum	8.6	1.5	82.5	Cultivation/introduction of potato + kidney bean
Fagopyrum esculentum	4.1	0.3	92.7	Cultivation/introduction of kidney bean
Parilla frutescense	1.3	–	100.0	Cultivation/introduction of soyabean
Setaria italica	2.3	0.8	65.2	Cultivation/introduction of soyabean
Oryza sativa (rainfed)*	11.2	11.2	–	Cultivation/introduction of HYVs
Eleusine coracana	9.6	6.1	36.5	Cultivation/introduction of soyabean + amaranth
Echinochloa frumentacea	2.5	0.7	72.0	Cultivation/introduction of pigeonpea
Vigna spp.	3.3	–	100.0	Cultivation/introduction of pigeonpea + amaranth
Rabi season crops				
*Triticum aestivum** + *Brassica* spp.	14.2	14.2	–	Cultivation/introduction of HYVs
Hordeum himalayens	17.1	4.7	72.5	Cultivation/introduction of potato, amaranth + kidney bean
Hordeum vulgare	7.0	1.1	84.3	Cultivation/introduction of HYVs
Brassica compestris	2.0	2.0	–	–

For measuring the extent of decline in the cropping area under different crops over the period of two decades, 150 villages distributed ove altitudinal gradient of 500–2400 m amsl in 11 valleys, viz. Niti, Mana, Pinder, Birahi, Urgam, Mandakini, Banger, Mandal, Jalchaumasi, Nandakir of Alaknanda catchment were surveyed.
*Though the area under above crops has not changed, the traditional varieties/landraces have been replaced by the high-yielding varieties (HYVs

Table 3. Per capita annual consumption of traditional crops by the locals in relation to other food items along an altitudinal gradient of Central Himalaya in 1970–74 and 1990–94 (after Maikhuri *et al.*[5])

Food items	Lower altitude (500–1000 m amsl) villages			Middle altitude (1000–1800 m amsl) villages			Higher altitude (1800–2400 m amsl) villages		
	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)
1970–74									
Common crops produced locally*	105.00	1637.60	12.00	92.00	1441.00	10.00	58.00	903.00	7.70
Traditional crops produced locally**	86.40	1170.40	9.35	90.40	1252.60	10.86	150.60	2085.00	17.70
Food grains imported from outside the village***	3.00	51.40	0.70	–	–	–	–	–	–
Animal products	97.20	295.30	4.90	127.20	384.30	6.20	206.80	627.00	10.50
Vegetables	16.00	248.80	1.32	26.0	404.30	2.15	85.00	1321.00	7.0
Total	307.60	3403.50	28.27	335.60	3482.20	29.21	500.40	4936.00	42.90
1990–94									
Common crops produced locally*	119.90	1942.50	11.70	103.70	1680.00	8.80	49.80	806.70	4.60
Traditional crops produced locally**	24.90	369.80	3.79	70.40	963.40	8.68	122.80	1730.20	15.70
Food grains imported from outside the village***	68.70	1119.70	7.28	54.40	885.10	5.83	56.10	908.80	4.60
Animal products	50.50	152.70	2.66	74.20	227.80	3.90	102.30	323.60	6.40
Vegetables	20.50	318.80	1.70	26.50	412.50	1.90	40.60	631.30	3.50
Total	284.50	3903.50	27.13	329.20	4168.80	29.10	371.60	4400.60	34.80

*The common crops include wheat and rice, and easily available in market.
**Excluding wheat and rice, the common food crops, all other crops clubbed as traditional crops.
***Food grains imported refers to the amount procured from outside the village through barter or cash-based market.

maximization of profits through monocropping of cash crops (including both traditional and introduced crops and cultivars) and (f) lack of incentives for marketing of traditional crops. Maximization of economic returns is an important but not the sole factor guiding the choice of crops. Social, ecological and policy factors significantly influence the cropping patterns. Traditional millets and pseudocereals are generally considered to be the food of the poor. Policy interventions have encouraged improvement in production of a selected few common food crops like paddy and wheat ignoring the diversity and specificities of the mountain agriculture[5,6,9].

The vast genetic resource base plays a crucial role in maintaining the long-term stability of traditional agricultural system in a number of ways: it increases productivity through fuller utilization of environmental resources, improves soil fertility when legumes are incorporated in the crop mixture, reduces the chances of pest, pathogen and weed infestations, conserves soil nutrients, checks soil erosion and produces a rich and balanced nutritional diet. Traditional agriculture is entirely based on local resources while the modern agriculture operates based largely on external inputs. Dependency on external inputs is the major risk in inaccessible mountain villages[11–13]. Further, traditional cultivars provide parent genetic material for developing artificially bred HYVs[2–4]. A food system based on only two or three food crops is extremely vulnerable to risks and is likely to be nutritionally unbalanced[4]. There are numerous examples in history about the serious economic losses while relying on few homogeneous varieties. Among important examples are the potato famine of Ireland in 1846, the great rice famine of India in 1943, and the US maize crop damage in 1970. In contrast to this, in the traditional diversified agriculture, during unpredictable bad climate years, local food security may depend on stress-tolerant traditional staples such as millets. Traditional pulses (horsegram and *Vigna* spp.) have 1.5 to 2.0 times higher protein content than wheat HYVs and 2 to 4 times higher than that of rice HYVs. Certain traditional crops such as *Panicum miliaceum*, *Setaria italica*, *Fagopyrum* spp. if necessary, can be harvested over a period of 50 to 90 days[5]. HYVs of wheat and paddy do enable higher yields compared to traditional cultivars of these crops[12]. However, the potential yields are often not realized because of poor irrigation system and poor access to fertilizers/pesticides due to mountain-specific constraints[9,13,14]. Unless timely availability of yield increasing inputs is ensured, a change from traditional crops to HYVs may not dilute the problems of hill farming. Several advantages of traditional agriculture mentioned above can also be had with the modern agriculture, but our data suggests that value of a diversified farming system is marginalized once the HYVs are available to the hill farmers. Indeed, these trends observed in the Central Himalaya cannot be generalized for other areas.

A majority of the traditional crops possess immense medicinal properties. The grains of *Setaria italica*, *Panicum miliaceum* and *Echinochloa frumentacea* are used in jaundice, pneumonia and many other abdominal ailments. *Macrotyloma uniflorum* is used to dissolve kidney stones. The traditional landraces have high ecological and economic potential and thrive well even under adverse environmental conditions[11]. The FAO Committee on World Food Security defined food security as the economic and physical access to food, for all people, at all times. Many food-scarce areas of Central Himalaya are forced to purchase large quantities of grains from outside to meet local production shortfalls. Payments for food imports are a big burden on the regional economy. Increased production and consumption of traditional food staples such as millets/minor grains, pseudocereals and pulses will increase food supplies and broaden the food base at household and region level.

Crop yield data at two points in time (Figure 1) suggests that yields of most of the traditional food crops have remained stable. Thus, the food insecurity or shortage problem seems largely due to the changes in food habits (increasing preference for wheat and rice as staples), reduction in crop diversity and net sown area, and population growth rather than due to decline in yields of traditional crops. Many traditional mountain crops have comparative market advantages. Potential economic returns from amaranths and buckwheat are over two-fold of the returns from HYVs of wheat and paddy[5]. Farmers are unable to realize profits because of small and fragmented holdings, lack of policy protection to small and marginal hill farmers and exploitation by the middlemen in the marketing channel[12–14]. Enhancement of local marketing and value addition capacity could trigger conservation of traditional crops together with economic development.

In spite of many virtues of traditional crops, we are still losing the precious genetic diversity, the rivets of ecosystems' stability, gradually. If serious view of the existing situation is not taken into account, the Central Himalaya will always remain a food-importing region and loose badly in terms of ecological and economic security. It becomes particularly significant when population is increasing. It has been predicted that by the turn of the century around 6% (62 millions) of India's population will be living in the Himalaya. Furthermore, the region would lose traditional knowledge of cultivation and uses of these crops forever and would also lose the chance of being a diverse and nutritive food-producing region. *In situ* conservation of traditional crops and cultivars could succeed when these crops are strongly linked with economic development of hill farmers. Pragmatic multidisciplinary research efforts are needed to

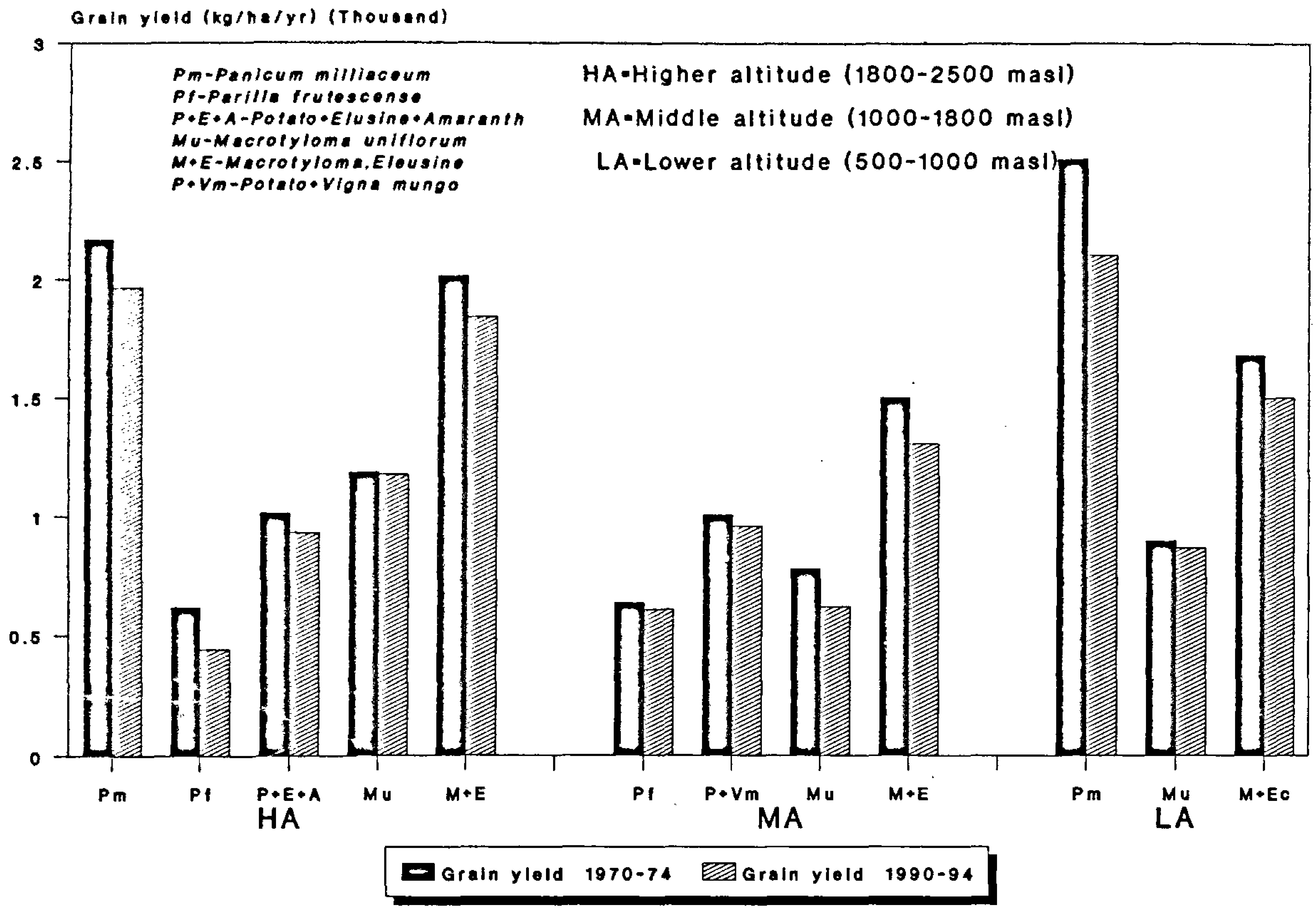


Figure 1. Crop yield (kg × thousand/ha/yr) of various traditional crops across an altitudinal gradient in different valleys of the Alaknanda catchment of the Central Himalaya at two points of time.

evolve farming systems which can provide enough quality food and economic security to the people of the region together with conservation of the traditional crop wealth, sustainability of the production systems and environmental conservation. Innovations built on integration of advantages of traditional and modern production technologies could offer more effective ways of addressing the problems of mountain farming system than a strategy aiming for replacement of traditional agriculture by the modern one. Poor scientific knowledge on traditional hill farming and socio-economic dimensions of hill farming society is a serious impediment in identifying sustainable agricultural development solutions in the Himalayas.

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