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Horticultural Research in the Himalayan Hill Region of India

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Introduction

The Himalayan hill region covers more than one-eighth of the total land area of India and makes up the entire northern boundary running from Jammu and Kashmir in the west to Arunachal Pradesh in the east. The economic condition of the people inhabiting this region is poor. Land holdings are small, scattered, and uneconomic. Irrigation facilities are limited and there is serious land degradation due to overgrazing, deforestation, and inappropriate land use. However, the agroclimatic conditions prevailing in this region are most suitable for the production of a number of horticultural crops on a commercial scale. These crops are more profitable per unit area and are also labour intensive, which generates more employment and can improve the economic condition of the people of the region. Horticulture is, therefore, considered the best way to exploit the region's natural resources, increase farm income, generate employment, and conserve land resources.

In the post-partition period, great strides were made in temperate fruit production in the hilly areas of the country, particularly in the northwest hill region comprising the states of Jammu and Kashmir, Himachal Pradesh, and the hill districts of Uttar Pradesh, located between latitudes 28° and 36°N. Simultaneously, efforts have also been made by both the Indian Council of Agricultural Research (ICAR) and the state governments to create a sound research infrastructure which has yielded several useful introductions, new cultivars, and agro-technology for improved productivity. This paper describes the infrastructural facilities

available and achievements made in growing fruits and vegetables, including potato, with special reference to the northwestern Himalayan region of India.

Fruit Research Infrastructure

The ICAR has been the premier agency to pioneer systematic temperate fruit research in the country. Research stations started with the initial help of the ICAR now form the nucleus of research in various states of the country. Notable among these in Uttar Pradesh has been the government Hill Fruit Research Station at Chaubattia, which was established as early as 1932 and was the first of its kind in southeast Asia. During the last two decades or so, work on temperate fruit research has also been initiated at the Fruit Research Station, Chakrata, in Uttar Pradesh. Some research on temperate fruits is also being conducted by the G.B. Pant University of Agriculture and Technology. The mid-hill zone is served by a research station at Majhera and the high zone by the Zonal Research Station at Ranichauri.

In Jammu and Kashmir, research on temperate fruits was initiated at the Fruit Research Station, Shalimar, Srinagar, in April 1945 with the introduction of a Survey of Deciduous Fruits by the ICAR. Subsequently, another scheme, Research on Fruits in Kashmir, was started in Collaboration with ICAR in June, 1955. This scheme was subsequently merged in August 1959 with the Establishment of Regional Fruit Research Station for Intensification of Research on Temperate Fruits in Kashmir. In 1972/73, a sub-station at Balapora, Shopian, was added to cater for the needs of high elevation fruit growing. Recently, the entire horticulture research in the state has been brought under the purview of the Sher-e-Kashmir University of Agriculture and Technology established at Srinagar in 1982.

With a view to exploit the fruit-growing potential in Himachal Pradesh, a comprehensive Fruit Research Scheme funded by ICAR was started at Mashobra during 1954 for temperate fruits. This station was elevated to the status of a Regional Fruit Research Station for temperate fruits during 1959. Later, a National Hortorium was established at Kotkhai during 1961 by the ICAR for the collection, maintenance, and evaluation of temperate fruit germplasm. A raisin research centre was also started at Sharbo during 1959 with the objective of evaluating the performance of grape varieties under arid conditions in Himachal Pradesh. Similarly, a research station was started at Boktu in Kinnaur district in 1960 to carry out research on drying varieties of apricot, almond, and walnut. Fruit research stations were also established at Khadrala and Bagthan in 1965 with funds provided by ICAR, to solve the problems of fruit cultivation in high altitude and low altitude

zones respectively. Similarly, research work on olive and pomegranate is under way at the Fruit Research Station, Kothipura, Bilaspur. Work on these fruits is also conducted at the Fruit Research Station, Borlaugh. Under the Himachal Agricultural University, work was started at Stokes Campus, Nauni, Solan, in 1971. The entire research work on fruit crops in Himachal Pradesh is now under the purview of the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan.

A Horticultural Research Station was also established in 1950 at Kulu, erstwhile Punjab, to develop the fruit industry in Kulu valley. The station made a good start, but later functioned primarily as a development centre. During the late 1950, a vegetable production farm, started at Kandaghat in the year 1921, was converted into a research station for stone fruits. The ICAR funded this station during 1960/61. The ICAR, New Delhi, sanctioned a project entitled Centre of Advanced Studies in Temperate Horticulture with UNDP/FAO assistance under the Himachal Pradesh Agricultural University, Solan, in 1979 to improve research and the quality of post-graduate education in temperate horticulture. On December 1, 1985 the Dr. Y.S. Parmar University of Horticulture and Forestry was established in Solan in Himachal Pradesh to boost horticultural research and development in the state and the entire horticulture research in Himachal Pradesh has been transferred to this university.

In the eastern region, a project was initiated during 1975 which grew into a full-fledged institute with regional stations in all the northeastern states. The institute, known as ICAR Research Complex for the northeast region, is located in Shillong.

The Indian Agricultural Research Institute (IARI) is also conducting work on temperate fruits through its Division of Horticulture at its Regional Station at Shimla, which came into existence in October 1965 for the collection, maintenance, and use of wild germplasm in pome and stone fruits. Work on virus aspects is also being carried out at IARI substation at Flowerdale and on plant introduction by the National Bureau of Plant Genetic Resources Regional Station at Phagli.

Temperate fruit research got a further fillip with the start of the All India Co-ordinated Fruit Improvement Project under the aegis of the ICAR during the Fourth Five-year Plan in 1968. Several ad hoc schemes are also under way to study specific problems of these fruits. A full-fledged Central Institute for Temperate Horticulture has been approved, to be established by the ICAR near Srinagar in Jammu and Kashmir during the current plan. The efforts of universities in the northwest region are also being further strengthened in different agroclimatic zones under the National Agriculture Research Project.

The research stations in the different states have been working on important problems of temperate fruits, including varietal evaluation and

improvement, propagation and rootstock, training and pruning, orchard management, nutrition, use of growth regulators, pest and disease control, and, lately, post-harvest management.

Fruit Research Achievements

Crop Improvement

Collection and Evaluation of Genetic Resources

The earliest record of varieties of fruits growing in Kashmir is found in the Gazetteer of Kashmir and Ladakh published in 1890. It lists Ambri as the leading apple variety. During the 20th century, great emphasis has been laid on the introduction and evaluation of the genetic resources of various fruits. While significant contribution in this regard were made at the beginning of the 20th century by missionaries, planned introductions have been made during the last three decades, mainly from Argentina, Australia, Bulgaria, Canada, Germany, Greece, Iran, Israel, Italy, Japan, Kenya, the Netherlands, Syria, the United Kingdom, the United States and the U.S.S.R.

As a result, a good collection of germplasm of pome, stone, and nut fruits has been made at 19 research centres, 11 of which are located in the northwest Himalayan region. Recently, an inventory of germplasm collection of pome, stone, and nut fruits has been compiled (Yadav, 1988) which lists species and varieties available in India. Accordingly, the number of varieties now existing in germplasm collection in India is apple 849, pear 165, apricot 98, cherry 11, peach 215, plum 280, almond 154, filbert 2, hazelnut 16, pecan 7, hecan 1, walnut 63, and other nuts 4.

India also has a wealth of wild germplasm collected from within and outside the country which offers an opportunity to breed suitable rootstock as a source of resistance and in several other ways. These include various genera, namely, *Amygdalus* (1), *Cary* (2), *Corrylus* (2), *Cotoneaster* (7), *Crataegus* (2), *Cytonia* (1), *Docynia* (1), *Juglans* (8), *Pyrus* (7), and *Sorbus* (3). The performance of various cultivars has been studied both in the collection blocks and through systematic varietal trials and suitable cultivars have been recommended for different areas in various states. A list of promising cultivars identified in Himachal Pradesh is given in Annex 1. Besides this, a number of promising apple cultivars have been identified by the evaluation of introductions. These are listed in Table 10.1.

Similarly, in peach, on the basis of tree growth, yield, and fruit quality, two exotic cultivars, Kanto 5 and Shimizu Hakuto, were found better than the existing recommended cultivars (Gautam *et al.*, 1986).

TABLE 10.1
Important categories of apple germplasm

Categories	Important cultivars
Non-spur type	Tydeman's Worcester, Stark Red Rome, Skymine Supreme, Red Delicious, Red Baron, Akane, Lalla Delicious, Lord Lambourne, Rose Red Delicious
Spur type	Starkrimson, Sky Spur, McSpur, Spur Type Golden Delicious, Bisbee Spur, Silver Spur, Gold Spur, Red Delicious
Low-chilling type	Vered, Michal, Maayan, Schlomit, Hybrid I, Tropical Beauty, Rome Beauty, Anna, Kidd's Orange Red
Scab-Resistant	Star Prize, Prima, Priscilla, Quinte, Liberty

COLLECTION AND EVALUATION OF INDIGENOUS WILD GERMPLASM OF POME AND STONE FRUITS

Several wild relatives of temperate fruits occur in the Himalaya. Surveys were conducted from 1966 to 1970 in several areas of Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh, and even Sikkim, Meghalaya, and Darjeeling district of West Bengal. As a result, 56 different species, varieties, and types of different genera covering pome, stone, and nut fruits were collected and conserved at IARI Regional Station, Amartara, Shimla: *Malus* (29), *Pyrus* (7), *Prunus* (15), *Crataegus* (2), *Cotoneaster* (7), *Docynia* (1), *Myrica* (1), *Cydonia* (1), *Sorbus* (3), *Fragaria* (1), and *Actinida* (1). The salient findings were reported by Randhawa (1987) and are given below:

- Seven different types of *Malus baccata* and one *Malus* sp. were studied. *Malus baccata* from Shillong and Khrot were as dwarfed as M-9. These two types have, therefore, potential as a dwarfing rootstock for apple.
- *Pyrus pyrifolia* has shown resistance to powdery mildew, fire blight, and collar rot and should be preferred over *pashia* and *pashia* var. *Kumaoni* as a rootstock for pear.
- Fourteen different species of *Prunus* were evaluated. *Prunus cornuta* was considered to be a better rootstock for cherry than *P. cerasoides*. *Prunus cornuta* and *P. persica* are susceptible to powdery mildew while *P. salicina* is resistant.
- *Crataegus*, *Cotoneaster*, and *Docynia* were found incompatible as rootstocks for both apple and pear.

DEVELOPMENT OF NEW VARIETIES

Hybridization work to evolve better varieties has been in progress in different states since 1960. In Himachal Pradesh and Jammu and Kashmir, efforts have been made to combine the dessert quality of the

delicious group with the good keeping quality of Ambri. As a result, two promising hybrids, namely, Lal Ambri (Red Delicious Ambri) and Sunehri (Ambri Golden Delicious), were released from Jammu and Kashmir during 1973. These have already gained popularity with farmers. Lal Ambri has a red-striped colour, whereas Sunehri has a sulphur yellow skin. Both varieties store well at room temperature and are considered an improvement over both the parents. In addition, eight newly synthesized hybrids are in the pipeline or under evaluation. Some scab-resistant varieties have also been crossed with commercially important varieties and are being evaluated at various locations in the Kashmir valley.

Similarly, from Mashobra, hybrid seedlings from crosses between Starking Delicious and Ambri gave four promising hybrids: Ambstarking, Ambroyal, Ambrich, and Ambred. While all these hybrids are late in maturing, Ambred has good fruit quality and better shelf life. Ambrich is a semi-spur type

In Uttar Pradesh, the apple breeding programme was initiated to evolve an early, red, sweet variety with good keeping quality. For this purpose, Early Shanberry, Fanny, and Benoni varieties were crossed with Red Delicious. Two hybrids of Early Shanberry and Red Delicious, namely, Chaubattia Princess and Chaubattia Anupam, are early ripening with an edible quality close to that of Red Delicious. Their keeping quality is better than that of either parent.

Introduction of New Crops

Efforts have also been made to domesticate new fruits in the temperate regions. Two important examples are olive and the Chinese gooseberry.

In northwestern Himalaya, the possibility of commercial cultivation of olive is provided by the presence of wild species, locally known as Kahu (*Olea cuspidata*) in concentrated belts at elevations ranging from 1000 to 1300 m above mean sea level. Systematic introductions of olive varieties were made under an Indo-Italian Project on the Development of Temperate Climate Fruit Crops in Jammu and Kashmir, Himachal Pradesh, and Uttar Pradesh. Nearly 1983, 2399, and 1202 trees have been planted in these states so far. The performance of six olive cultivars (*Olea europea* L.) studied in Nauni, Solan, has revealed that the cultivars Ascoiterana and Frantouo gave better yield and higher oil content than other cultivars (Singh *et al.*, 1986). Ripening of different varieties started in the first week of September and continued till the third week of December. The oil content ranged from 16.20 to 25.87 per cent.

The Chinese gooseberry is a promising fruit for lower hills. Four Chinese gooseberry cultivars introduced from the United States and New Zealand were evaluated at Phagli, Shimla, for 10 years. Among the four

cultivars, Abbott, Allison, Bruno and Hayward, Allison was the best for its earliness, yield, and total solid content (Rathore, 1987).

Pollination, Flowering, and Fruit Set

Several temperate fruit cultivars need pollinizers to raise commercial crops. Studies have been under way at different centres to find suitable pollinizers.

Among apple cultivars, Red Gold and Tydeman's Worcester have been found to be good pollinizers for cultivars McIntosh, Red Delicious, Richared, and Royal Delicious at Mashobra. These pollinizer cultivars are, however, themselves partially or fully self-fruitful. At Chaubattia, good fruit setting was reported in Red Delicious with Jonathan, Buckingham, and Esopus Spitzenberg. Of these, however, Buckingham is preferred commercially. For Early Shanberry, cultivars Fanny, Winter Banana, and Rome Beauty were found to be better pollinizers.

Studies on the varying proportion and distribution of pollinizer trees indicated that where the proportion of pollinizer trees was 33.33 per cent, the percentage of fruit set in open pollination was fairly high. Fruit set reduced when pollinizer trees were fewer than 12.5 per cent.

In plum, the cultivar Beauty, which flowers profusely, has been recommended as the best pollinizer for commercial adaptability in Santa Rosa orchards in Himachal Pradesh. At Chaubattia, however, New Plum proved to be a good pollinizer for all the European plums, while Santa Rosa was best for all Japanese plums.

In almonds, the cultivars Thin Shelled, Nonpareil, and Ne Plus Ultra were found to be self-incompatible and Drake to be self-fruitful in Himachal Pradesh. Nonpareil was reported to be the best pollinizer for all varieties except Ne Plus Ultra. Therefore, no single almond cultivar should be planted in a compact block and a combination of two or more is a must for successful almond cultivation. A combination of Nonpareil, Thin Shelled, and Drake has been finally recommended for commercial cultivation in Himachal Pradesh.

Pollination studies have also been undertaken with identified varieties and local selections in Jammu and Kashmir. HS-2, a local selection, is a good pollinizer for HS-8, HS-1, and Primorskij. Nonpareil and Nikitskij have been found to be good inter-pollinizers. HS-15 and Afghanistan seedlings are incompatible with each other and with HS-15.

Observation by Awasthi *et al.* (1986) at Mashobra for a period of 13 years has revealed that climatic conditions during flowering in March-April greatly influence the time of flowering, fruit set, and yield of Royal Delicious apple. During the pre-bloom period in March a maximum temperature around 10°C delayed flowering, whereas above 15°C enhanced it. Average maximum and minimum temperatures around 20°C and

10°C respectively during flowering in April produced good fruit set. High relative humidity above 50 per cent in March delayed flowering, without affecting fruit set. Rainfall during flowering in April adversely affected fruit set.

In Himachal Pradesh, SADH,at concentrations ranging from 2000 to 8000 ppm, was effective in delaying the time of flowering of Royal Delicious while succinic acid at 600 to 800 ppm sprayed one month before bud burst was effective in delaying the blooming period of almond.

Physiological studies of Royal Delicious variety revealed that erratic and irregular flowering under Solan conditions was due to temperature fluctuations in spring and the problem was solved by the application of PP333 at 500 ppm or GA at 50 ppm after cessation of growth. Similarly, under high hill conditions increased fruit set was achieved in Royal Delicious by the application of 100 ppm GA plus 40 ppm NAA at pink bud stage.

In strawberry, the application of 100 ppm CCC 15 days before flowering in Himachal Pradesh improved growth, flowering, fruit set, and quality of Senga Sengana, Tioga, and Missionary cultivars.

Crop Production Technology

Propagation Techniques

While vegetative propagation techniques in pome and stone fruits are well known, propagation has been difficult and techniques known in certain nut crops. Constant efforts have, therefore, been made to improve known techniques in pome and stone fruits and to standardize new propagation techniques for nut crops. The results obtained for various crops are summarized below.

In apple, success up to 70 per cent has been achieved in rooting hard wood cuttings of crab under glasshouse conditions at Chaubattia. Treatment with 2500 ppm IBA improved rooting (Pathak and Pandey, 1984). With the use of IBA 2500 ppm, rooting was increased by stooling in M 109 and M7 rootstocks (Srivastava and Joshi, 1984). Provision of bottom heat (21 + 2°C) was essential for root initiation during the dormant season. Chip budding during August-September and tongue grafting during February-March 10–15 cm above collar has been recommended to save plants from root rot and collar rot (Chadha, 1978). In Uttar Pradesh, up to 80 per cent success in rooting of crab-apple stool layers was achieved by the application of 2500 ppm IBA in a lanolin paste. Similarly, 84 per cent success in rooting of stool layers of MM 106 was achieved by the application of 2000 ppm of IBA in lanolin paste (Chauhan, 1987).

In Himachal Pradesh, the stooling performance of nine clonal rootstocks—M2, M7, M9, M25, MM 104, MM 106, MM 108, MM 110, and

MM 111—was studied at Fruit Research Station, Kotkhai. Rootstocks MM 110 and MM 106 produced more rooted suckers. Other rootstocks produced medium or low suckers. Rootstock MM 110 produced the most vigorous suckers. A good root system was recorded in Malling Merton Series of clonal rootstocks under study (Rana *et al.*, 1986).

Air-layering was tried in cultivars Fanny, Early Shanberry, and Rymer. Air-layers treated with 5000 ppm IBA gave best results (60 per cent rooting) in Fanny. A rooting percentage of 60 to 70 was found in Early Shanberry and Rymer respectively with the application of 7500 ppm of IBA (Chauhan, 1987).

In pear, some success has been reported in shoot layering by the application of 500 ppm of IBA after ringing in Uttar Pradesh at Chaubattia; however, 2500 ppm of IBA induced maximum rooting in the cultivars Patharanakh and Gola, with provision of bottom heat (Chadha, 1978).

Plum cultivars Santa Rosa, Mariposa, and Greengage, bench grafted on five different rootstocks—wild peach wild apricot (*Behmi*—a natural hybrid of almond and wild peach), bitter almond (*Prunus amygdalus*, and Myrobalan B (*P. cerasifera*)—gave varying drafting success from zero to 100 per cent. Wild peach and Myrobalan gave the best results and bitter almond and Behmi the poorest. Among scions, Mariposa was most successful on a greater range of rootstocks (Sharma and Sharma, 1986).

At Chaubattia, IBA 1000 ppm was found to promote the rooting of cuttings in plum. Mist was favourable for rooting and success was greater in December (Chauhan and Reddy, 1978).

Stratification of cherry stones in a sand + soil (3:1) medium from May onwards gave the highest germination. Also, stooling of cherry seedlings has been induced with and without application of IBA.

For the vegetative propagation of persimmon, veneer grafting done during the second half of September at Nauni, Solan gave 97.67 per cent success and proved to be an excellent method of vegetative propagation (Chauhan and Gautam, 1986).

Concerted efforts to vegetatively propagate walnut have been made in Himachal Pradesh, Uttar Pradesh, and Jammu and Kashmir. In Himachal Pradesh patch budding gave up to 72 per cent success in 1961. Later, during 1967, a modified forkert method of budding done from mid-June to the first week of July was found to be the best in Kinnaur area of Himachal Pradesh. Further, veneer grafting was reported to be the best method at Kandaghat during 1968. During 1975, however, at Solan, storage of cleft and tongue grafts in an incubator at $25 \pm 1°C$ for weeks prior to planting gave a high percentage of successful grafts.

From Chaubattia, a maximum success rate of 80 per cent was reported by cleft grafting during 1971. Alkathene of 400 gauge was found to be the best tying material. Later, during 1975, modified patch budding with the help of a double-bladed knife was successful between mid-

June and mid-August. Vegetative buds showed better success and are recommended to be used as scions. For best results, budding should be performed as early as possible after collecting the scion (Chadha, 1978). In walnut, stooling was attempted in Jammu and Kashmir by Rashid (1978) using growth regulators. A combination of 10,000 ppm of IBA and 5000 ppm of NAA was most effective in increasing the rooting of walnut stools.

In Jammu and Kashmir, three methods of budding and two methods of grafting have been tried at different times. Budding was found to be more successful, especially patch budding.

In pecan, maximum rooting was obtained in the semi-hard wood of juvenile cuttings, treated with 500 ppm IBA and planted when misty during summer.

Standardization of Rootstocks

Since there is a lack of uniformity in tree size and cropping of plants propagated on seedling rootstocks, clonal rootstocks of Malling and Malling Merton series were introduced from East Malling Research Station, England to Mashobra and Kotkhai in Himachal Pradesh; Chaubattia in Uttar Pradesh, and Shalimar in Jammu and Kashmir. These rootstocks offered the possibility of having trees of the desired size from dwarf to very tall, besides which, the MM rootstocks are resistant to woolly aphid. Varietal and rootstock trials have been in progress at Mashobra (1967), Kotkhai (1968), Chaubattia (1969), and several locations in Jammu and Kashmir. Simultaneously, commercial usage started in the early 1950s in India. Until then, the nurseries in Kashmir, Kumaon hills, Kulu valley, and other hill regions have been using crab-apple as a rootstock for apple. Similarly, in pear, the common rootstock has been *Pyrus pashia*, called Kainth or Shiara. Quince was occasionally used to produce dwarf pear plants. For peach and plum, apricot and plum were used.

Among the Malling series, M 9 and the Malling Merton series MM 110 and MM 111 were considered to be most dwarfing, based on stomatal density (Jindal and Rana, 1984). Randhawa and Kishore (1984) observed Malus baccata Shillong, a native type, to be as dwarfing as the M9 rootstock.

Rootstock trials conducted in the Uttar Pradesh hills have shown that M9 rootstock is not suitable for this area because soil depth is low; the shallow root system of M9 stock results in heavy casualties under drought conditions. Among vigorous rootstock, MM 104 has shown better results. Studies also indicate that M9 exerts a dwarfing effect as an intermediate stock (Chauhan, 1987). However, growth as well as yield are higher in vigorous rootstock. Srivastava (1966) recommended Merton 779 rootstock for apple in Chaubattia and on a commercial scale for Kumaon hills considering its overall performance. Rootstock trials con-

ducted at Chaubattia also showed M25 to be the most promising in the dwarfing of apple trees.

The performance of commercially important varieties of apple on Malling and Merton rootstock is being assessed under various agroclimatic conditions in Jammu and Kashmir. Results indicate promising performance by M2, M4, M7, and M9. Further, Ambri apples on seedling rootstock came into bearing after 10–12 years of plantation. Precocity has been successfully induced through use of M9 and M26 rootstock/interstock (Kabu 1975). Studies conducted to evaluate different scion varieties of apple on *M. baccata* Khrot revealed that these rootstocks are as dwarfed as M9, are easy to propagate through mound layering, and have good graft compatibility with apple cultivar Golden Delicious (Randhawa and Kishore, 1986). Further screening of *Malus* species revealed that *M. sieboldii* (Sanashi 62) requires the least the chilling (Kishore and Randhawa, 1986).

Practically no work has been done on the standardization of rootstock for stone fruits. However, wild peach for peach and plum, wild apricot and bitter almond and wild peach for almond have been recommended from Chaubattia.

Three scions—Santa Rosa, Mariposa, and Greengage—were grafted on three rootstocks—wild peach, wild apricot, and Myrobalan rootstock. Wild peach was generally poor rootstock (Sharma and Sharma, 1986).

In Himachal Pradesh, rootstock studies conducted have resulted in the identification of promising rootstock for various fruits as under:

Apple	Dwarfing:	M9, M26
	Semi-dwarfing:	M7 and MM 106
	Semi-vigorous:	MM 111
Plum	Clonal:	Myrobalan B
	Seedling:	Wild apricot
Peach:		Wild peach seedling
Almond	Mid-hills:	Wild peach seedling
	High-hills:	Bitter almond seedling
Apricot:		Wild apricot (Chuli) seedling

Nutritional Needs

Nutrition of temperate fruits has not received enough attention in the past. The prevailing manurial practices were based on the experience of growers and there was considerable variation from orchard to orchard for the same variety and under similar agroclimatic regions. No serious attempts have so far been made to ascertain the validity of the prevailing practices nor to evolve suitable manurial schedules. Systematic and long-range fertilizer trials on apple were initiated in 1970 at Chaubattia (Uttar

Pradesh) and in 1975 at Mashobra (Himachal Pradesh). Work on other temperate fruit crops were started much later.

Salient results obtained are discussed below.

Apple

Seasonal variations in NPK content of Royal Delicious were studied by Verma and Singh (1986). Nitrogen content declined sharply in the active growth period from May to July and was stable during July. Phosphorus content showed no consistent seasonal trend, but K content generally decreased from May to August. After fruit harvest, increase in NPK, content was registered. The best time for collecting leaf samples was found to be July for N and P and August for K.

On the basis of fertilizer trials conducted in Uttar Pradesh, 25 g of N, 20 g of P205, and 25 g of K20 per year of age increasing up to 15 years is recommended. These doses are expected to give a yield of 9.5 tons/hectare. For apples on the dwarf rootstock M9, the recommended doses are 20 g of N, 10 g of P205, and 8 g of K20 per year of age, increasing up to seven years. These doses relate to the Delicious group of apple.

Under the conditions of Jammu and Kashmir, a fertilizer doze consisting of 600 g N and 900 g K20 was recommended for the White Dotted Red variety (Gani and Raina, 1984). Under Mashobra (Himachal Pradesh) conditions, application for NPK at 350:175:175 g respectively per tree was found to be adequate.

Foliar sprays of NPK have also been attempted. Foliar sprays of N and K increase the N and K content of apple leaves. With spray there was no response in P content of foliage. Fruit yield was not affected significantly, but fruit colour was improved by K and reduced by urea spray. Further urea spray improved weight and size of fruit and K spray increased T.S.S and acidity.

The leaf sampling technique in apple has also been standardized. Leaf sampling in the month of August is the best in order to study the nutrient status. It has also been found that 2.744 per cent P205 and 2.775 per cent K20 indicates abundant content, 1.685 per cent N, 0.228 per cent P205, and 2.234 per cent K30 optimal content, and below 1.685 per cent N, 0.171 per cent P205, and 1.693 per cent K20 a deficient level (Chauhan, 1987).

A study on the nutrient status of apple orchards in Himachal Pradesh has revealed that deficiency of NPK is fairly widespread in Himachal Pradesh. Out of the three fertilizer elements, phosphorus was the most limiting factor in apple production (Rana *et al.*, 1976). However, there was no response to phosphorus application in Jammu and Kashmir (Gani and Raina, 1984). Studies conducted by Karkara *et al.* (1986) have revealed that nutrient uptake is not affected by the source of N but with

increased N levels, the K and Mn content increased and the leaf P content decreased. Broadcasting the fertilizer was found to be convenient and as effective as pocket placement or trench application (Awasthi *et al.*, 1984). Application of 225 g N in soil and 75 g to the foliage was found optimum for Red Delicious under Mashobra (Himachal Pradesh) conditions (Awasthi *et al.*, 1976). Foliar application of potassium sulphate was found to be effective in increasing the yield (Divakar, 1976).

Micronutrient disorders have become widespread in Himachal Pradesh due to zinc, copper, and boron deficiencies. Tomar *et al.* (1970) reported moderate to acute zinc deficiency in Kulu valley, Himachal Pradesh. Boron deficiency in Rymer apple was reported in Himachal Pradesh by Dune *et al.* (1969). Pre-harvest fruit cracking in Cox's Orange Pippin variety occurring in Himachal Pradesh during the monsoon has been attributed to a combined deficiency of copper and boron by Pant (1969) and Pant *et al.* (1971).

Nutrient surveys carried out by Rana *et al.* (1976) in Himachal Pradesh as part of the All India Co-ordinated Fruit Improvement Project revealed the deficiency of all nutrients, except magnesium and iron.

Control of micronutrient deficiencies of various elements has also been studied. Zinc deficiency in apple can be corrected either by foliar sprays of 0.5 per cent $ZnSO_4$ or the application of zinc sulphate in the soil at 100 g/tree. Boron deficiency is best controlled by twice spraying with 0.4 per cent boric acid, once at petal fall and again within a month of the first spray. Pre-harvest cracking due to copper and boron deficiency can be tackled by combined sprays of 0.4 per cent borax and 0.05 per cent copper sulphate, once at fruit set and twice at fortnightly intervals after the first spray. Apple measles, caused by toxicity of manganese, can be controlled by the application of lime to the soil at the rate of 1 kg/tree. Zinc deficiency resulting in little leaf can be controlled by foliar spray with zinc sulphate, 0.4 per cent combined with 0.2 per cent lime (Chauhan, 1987).

Foliar application of borax at 70 ppm or application to the soil at 100 gm after harvest, but before leaf fall followed by another spray at pink bud, was effective in controlling boron deficiency (Bhat and Singh, 1984).

Plum

It is recommended that 36 kg of farmyard manure, 720 g calcium ammonium nitrate, 570 g of superphosphate, and 360 g of muriate of potash be applied to a full bearing plum tree. Foliar feeding of plum trees with 0.5 per cent urea was found to increase the efficiency of nitrogen fertilizers. The entire quantity of nitrogen at 1.044 kg., when applied in a single dose in February, was effective for fruit retention and yield, whereas application in two doses, once each in February and April, increased fruit size. Foliar application of 0.6 per cent zinc sulphate, together with 0.2 per

cent copper sulphate, increased fruit retention and eventually the yield per tree (Mann *et al.*, 1984).

Studies on leaf nutrient standards in plum revealed that the period from June 20 to July 15 is the most suitable for leaf sampling.

Apricot

Applications of nitrogenous fertilizers were found to increase the apricot yield in Uttar Pradesh. When nitrogen was applied along with phosphorus and potash, fruit yield as well as individual fruit size was found to increase. Individually, nitrogen at 450 g/tree was found to be optimum. The yield maximizing combination of N, P_2O_5, and K_2O was observed to be 56.7, 28.35, and 68.04 g respectively for each year age of the tree; while 500 g N was optimum for New Castle apricot, 300 g was adequate for Shipley's Early cultivar.

Almond

In Kashmir, nut weight and kernel weight was found increased with fertilizer application of NPK but fruit maturity was delayed.

Training and Pruning

Comprehensive training trials have been under way at various centres under the All India Co-ordinated Fruit Improvement Project. Modified central leader or open central leader system has been found to be good for apple cultivar Red Delicious on M7 rootstock, and the espalier system of training proved best for Red Delicious with respect to dwarfing, yield, and quality of fruit (Anon., 1984).

Studies conducted to determine the intensity of pruning in the apple variety Royal Delicious revealed that moderate pruning involving 40 per cent growth was good while light pruning (20 per cent) and no pruning control impaired tree health and reduced the yield (Ram Kumar and Srivastava, 1982).

Summer pruning of apple has also been tried to enhance colour development. The removal of current year twigs and one metre long current-year wood gave 37 per cent more fruits conforming to A grade (80–100 per cent colour) compared to 23 per cent in controlled conditions.

Very little research on pruning of stone fruits has been done in India. Some pruning trials have been conducted on Elberta peach at Palampur (Himachal Pradesh) which have indicated that light pruning increased fruit yield, while severe pruning improved the quality. Therefore, it was recommended that 75 per cent of the previous year's growth be retained (Badiyala and Bhutani, 1984).

Orchard Management

Since apple is grown on light soil under rainfed and moisture stress conditions in Uttar Pradesh, attempts have been made to conserve soil moisture and control weeds through mulching. Experiments conducted with various mulches on Royal Delicious cultivar with MM 106 rootstock have shown that all the mulches have been able to conserve more moisture and reduce weeds, thereby increasing growth of apple grafts. The percentage of saleable plants increased from 50.5 per cent in control to 64.3 per cent in a black polythene mulch (Chauhan, 1987).

In Jammu and Kashmir, perennial fodder, especially red clover, can be grown successfully in the open spaces of young orchards beyond the canopies of fruit trees. Red clover successfully establishes itself, even in old orchards under the canopy of fully grown trees, but due care needs to be taken of the problems associated with it (Kaul et. al., 1978).

In Himachal Pradesh, black polythene was observed to be good mulching material for apple in the high hill region, but unsatisfactory as a mulch in the lower and mid-hill areas, because of its deleterious effects. Mulching with grass or hay or without herbicides like Simazine at 5 kg/hectare plus glyphos at 2.5 kg/hectare is highly effective in maintaining a higher moisture level and lower temperature in the soil throughout the growing season, resulting in better growth and higher yield of some fruits.

Experiments on the use of herbicides for the control of weeds in orchards and nurseries have been under way at several places. At Mashobra, Gramaxone spray at 3.75 hectare controlled annual grass and broad-leaved weeds for a period of two to three months in apple orchards. Summer spraying was found more effective than spraying in spring or autumn. A mixture of 2, 4, 5-T at 1000 ppm and Gramaxone at 500 ppm showed a long-lasting effect in controlling weeds Atrazine (at 5, 10, 15 kg/hectare) gave better results than Simazine at the same rate. Each herbicide at 4.5 kg/hectare gave 84–89 per cent control, compared to 74 per cent with hand weeding.

In plum, both Diuron and Razine at 4 kg/hectare proved effective in controlling weeds but Diuron maintained its superiority to Atrazine during both the years. No phytotoxic effects were noticed (Khodhar *et al.* 1986). Diuron and Atrazine at 4 kg/hectare each were found to stimulate the activities of amylase and invertase, whereas cellulose activity remained unaffected (Khokhar *et al.* 1986).

Regardless of herbicidal treatment, different levels on N improved markedly the nitrogen, calcium and magnesium content, while phosphorus and potassium remained unaltered. Simazine and Terbacil may partly substitute for nitrogen fertilizer in Santa Rosa plum (Bhutani and Bhatia, 1986).

Crop Regulation

Significant achievements have been made in crop regulation of temperate fruits, particularly with the use of chemicals and plant growth regulators. These are described below.

Application of SADH at concentrations ranging from 2000 to 8000 ppm was effective in delaying flowering of Royal Delicious apple (Singh and Jindal, 1986). Thiourea at 5000 ppm delayed bud break in Royal Delicious apple (Jindal and Singh, 1986). Kinetin at 12.5 ppm advanced flower opening. In almond, succinic acid at 600 to 800 ppm, sprayed one month before bud burst, was effective in delaying blossom.

A critical analysis of the problem of overbearing in many temperate fruits reveals that judicious thinning, suitably employed at the proper stage of fruit development, can regularize cropping with good-sized, well-developed, and superb quality fruit. Considerable work on this aspect has been done in the case of apple, plum, and apricot.

In apple, carbaryl (Sevin) at 750 ppm, sprayed 7–10 days after the petal fall stage, proved to be most effective for fruit thinning. NAA 30 ppm and Hexavin (85 per cent W.P.) at 1000 pm were also rated good thinners. At Chaubattia, carbaryl at 1000 ppm induced maximum thinning and had an appreciable effect on quality (Chadha, 1978). Post-bloom spray with Ethephon at 100 and 200 ppm concentration was found to be effective for fruit thinning in apple and increased the superior yield of grade fruit by 40 per cent in Red Delicious (Wazir *et al.*, 1984).

In plum, hand thinning, keeping fruits 5–7 cm apart, and chemical sprays with DNOC and Sevin at 2000–2500 ppm at full bloom and a week after fruit set resulted in large fruits of Santa Rosa at Kandaghat. In recent years, Ethephon at 100 ppm sprayed 10 days after full bloom was found to be effective for fruit thinning and improving fruit quality in Beauty plum.

In apricot, NAA at 100 ppm at petal fall stage has been reported to give good thinning results.

Several studies have been made to control pre-harvest drop, particularly in apple. Spraying with Planofix containing 10 ppm of NAA three weeks before harvest or 7–10 days before actual drop, has been found to be highly effective in checking pre-harvest fruit drop and improving fruit size in Delicious apples in Himachal Pradesh. In late-maturing cultivars like Granny Smith, spraying with CCC at 200–300 ppm three weeks before harvest was found to be most effective.

Planofix sprays have also been found to check drop when apple harvesting was delayed by about a fortnight to avoid a glut in the market. NAA and 2, 4, 5-T each at 20 ppm sprayed two weeks prior to normal harvesting significantly decreased pre-harvest drop. In Golden Delicious, 2, 4, 5-T at 20 or 40 ppm applied a month prior to plucking had a ben-

eficial effect. 2, 4, 5-T at 10 ppm checked drop in Red Delicious apple (Chadha, 1978).

In apricot, sprays of 2, 4, 5-T at 80 ppm have given best results for the New Castle variety (Chadha and Bajwa, 1968). GA 75 ppm, NAA 30 ppm, and 2, 4, 5-T ppm were other treatments found effective in controlling fruit drop.

The development of pigment in red apple cultivars is greatly inhibited in some areas situated at elevations of 1400–1700 m above mean sea level in the mid-hills of Himachal Pradesh. Spraying Ethephan at 100–1200 ppm in combination with 25 ppm NAA three weeks before harvest has been found very effective in enhancing red colour development and inducing uniform fruit maturity in such warm areas. Application of 3000 ppm of CEPA, combined with 2000 ppm of SADH 12 weeks after full bloom, was found to be the best for colouring Red Delicious apple and improving its quality.

In Jammu and Kashmir, experiments over a four-year period have shown that dipping Red Delicious fruit in 4 per cent calcium chloride solution for five minutes increased the calcium content of the fruit from 4.25 mg/100 g to 5.70 mg/100 g on a fresh weight basis.

Sprays with DNOC, at the rate of 2000–2500 ppm at full bloom and a week after fruit set, improved fruit size in Santa Rosa plum. Three applications of Ethephon 300 ppm at 10-day intervals commencing from 45 days before the normal date of harvesting hastened ripening in Santa Rosa plum. Concentrations above 100 ppm resulted in a dark purple colour. The application of Ethephon to advance ripening should be done 15 days before the normal harvesting time. Similarly, to induce ripening in plum, a post-harvest dip for one minute in 1500–2000 ppm Ethephon containing 0.05 per cent Teepol was found to be the best treatment at Solan.

TIBA at 10–25 ppm and SADH at 500 ppm has been found to significantly increase fruit firmness of Santa Rosa plum (Jindal and Mehta, 1986). The combination of Ca $(NO_3)_2$ with 10 ppm TIBA increased the anthocyanin content of fruit (Jindal and Sharma, 1986).

Crop Protection

Pests

More than 150 species of insect pests have been found to cause damage to temperate fruit in India. Work on bionomics and the control of some important pests is under way.

San Jose scale, *Quadraspisiotus perniciosus*, is a most destructive pest in Kashmir, Himachal Pradesh, the Uttar Pradesh hills and other eastern Himalayan regions of India. It is also reported as a serious pest of pear, peach, plum, cherry, and apricot. Biological control of this pest has

been tried. A Russian strain of *Prospartella perniciosi* gave as high as 9 per cent mortality of the pest. At Chaubattia, after release of American and Chinese strains, the pest population decreased by 95.73 and 94.78 per cent respectively. However, in commercial orchards control by parasites and predators is seldom sufficient to provide effective population suppression; consequently, one or two annual sprays are applied (Masoodi and Amin, 1978). Experiments have shown that oil emulsion sprays are more efficacious than organophosphoric insecticides and that dormant season application is better that summer spraying (Dar *et al.*, 1976). Work done in Himachal Pradesh revealed that 2 per cent miscible oil impregnated with organophosphatic insecticides like methyl parathion or fenitrothion 1 g for 1 hectare gives effective results (Sharma and Bhalla 1965).

The woolly aphid, *Erisoma lanigerum* (Hausman), is another serious pest of apple found in the northwestern hill region and the Nilgiris in Tamil Nadu. Successful biological control of the aphid has been achieved in the Kulu valley (Himachal Pradesh) by the introduction of an Aphelinid parasite *Aphlenus mali* Hald. Control was partly successful in Uttar Pradesh. *Coccinella septumpunctata* was also found feeding on all stages of the pest and giving almost complete control during summer in some Uttar Pradesh orchards. Work done on aphid-resistant rootstock has revealed that Golden Delicious, Northern Spy, and Stocks M-21, M-779, M-793, MM-111, MM-114, MM-115, and crab-apple (*M. baccata* L. var. Himalica) have been found highly resistant (Chauhan, 1987). The aerial population of the aphid can be controlled effectively by foliar sprays with fenitrothion, diazinon, dichlorvos as 0.05 per cent methyl demeton or thiometon 0.025 per cent and dimethoate 0.03 per cent in summer. Diazinon and methyl demeton are found less toxic to the parasite, *Aphelinuls mali*. For root infestation, the application of granules of demethoate, phorate, or disulfatan at 1 kg a.i./hectare is recommended (Chadha, 1978).

The codling moth, *Cydia pomonella*, is a serious pest of temperate fruit, mainly apple, in the Ladakh region of Jammu and Kashmir. It is absent in other parts of the state. The moth is active from May to July. The new hatched caterpillars bore into developing fruit causing the young fruits to fall off. The variety Thakush is most susceptible, while Karkitchu is least susceptible. Destruction of the fallen fruit and spraying with Dichlorvos are effective control measures.

Peach leaf curling aphid *Brachycaudus helichrysi* Kalt, is the most serious pest of peach and also attacks almond, apricot, and plum. Damage is caused by the nymphs and adults which suck sap from leaves, petioles, blossom, and fruit. The affected leaves turn pale and curl up, blossoms wither, and fruits do not develop to their normal size and drop prematurely. To control this aphid, 0.03 per cent dimethoate, oxydemeton, methyl phosphamidon, or quinalphos is sprayed before flowering (pink

bud stage), followed by one or two sprays when the fruit is pea-sized (Sharma *et al.* 1968).

Four species of fruitfly, namely *Dacus dorsalus, D. zonatus, D. ciliatus*, and *D. cucurbiatae*, have been found to infest peach fruits seriously in Himachal Pradesh and Uttar Pradesh. For their control, bait sprays with yeast hydrolysate + sugar + malathion 0.1 per cent are recommended. Sharma *et al.* (1973) suggested two sprays of fenthion or fenitrothion 2.5 ml a.i. per tree four and two weeks before harvest. Growing of early-maturing cultivars like 16–23 and Florida Sun are also recommended because they escape damage (Deol *et al.*, 1977).

Walnut weevil causes the premature dropping of fruit during June-July. During April, trees should be sprayed with 0.04 per cent quinalphos or 0.05 per cent dichlozvos.

Diseases

Systematic work on diseases of temperate fruits has been under way for the last three decades and work on epidemiology and control has been carried out.

Among various diseases which attack apple, the most destructive one is scab incited by a fungus *Venturia inaequalis*. This is particularly severe in areas with high rainfall and relative humidity. Losses from scab are greater than from any other disease or insect of apple. The apple scab fungus is only confined to apples (cultivated and crab) with the genus *Malus* and does not affect almond, apricot, peach, pear, plum, and other plants. Most of the apple varieties which are commonly grown in India are susceptible to scab. However, the locally evolved apple hybrids, Ambroyal, Ambred, and Ambstarking, were found to be fairly resistant to apple scab. Versified, popularly known as Maharaji, used to be free from scab but in recent years it has proved less resistant, a mild infection of the fruit having been noticed (Gupta and Lele, 1980).

The most striking symptoms of scab are commonly observed on leaves and fruit, but rarely on one-to three-year-old shoots (Gupta and Lele, 1976). The scab fungus consists of many strains which differ in their morphological, physiological, cultural, and pathogenic reactions.

Three main criteria—quantity and relative maturation of pseudothecia as a source of primary inoculum, phenology of the tree, and the occurrence of infection periods—form the basis of apple scab prediction in Himachal Pradesh which makes known the occurrence of infection before symptoms appear in the spring and helps growers to spray efficiently.

Adoption of certain means, e.g., 5 per cent urea spray at leaf fall (Gupta, 1979) to enhance the decomposition of leaves and keeping the orchard floor clean of fallen leaves, can help to reduce fungicidal application in the next season. A recommended spay schedule for the control of apple scab is given in Annex 2.

Hulling of Walnuts

The conventional method of walnut harvest, which consists of heaping up the walnuts so as to allow fermentation of hulls, is cumbersome and time consuming. It also stains the shells and hands of the huller and in some cases the kernel as well. Chemical hulling is more efficient.. This method also enables walnuts to be harvested earlier, keeping the kernels an attractive colour (Qureshi *et al.*, 1986).

Ethrel in various concentrations has been sprayed on trees and on nuts on the ground after harvest. Application of ethrel at the time of normal harvest in general resulted in a higher percentage of hulled walnuts in comparison to those treated one and two weeks before normal harvest (Qureshi *et al.*, 1986). Dipping the nuts in 2000 ppm ethrel resulted in great ease in hulling; the hulls either split on their own or could be removed easily. No staining was noticed on treated nuts. Even though spraying the nuts on the trees gave better results, trees of seedling origin being giant-sized, the operation is not practicable with the commonly used spraying equipment (Kabu, 1975).

Storage

Studies on apple storage carried out by Maini *et al.* (1985) revealed that firmness of the fruit decreased in storage. Dry matter, acidity, fibre, and tannin did not show any particular trend. Fruits showing a firmness of 7.5 lb or less should not be stored but should be disposed of immediately. In Jammu and Kashmir, studies on prolonging the storage life of Red Delicious apple by use of various wrappings have shown a definite advantage in the use of polythene 1 mm bags over the use of waxed paper, oiled tissue paper, or no wrapping at all. It resulted in minimum loss in fruit weight and maintained taste and crispness for a longer time (Bhat and Kabu, 1972). Apples placed in the controlled atmosphere storage at Srinagar remained fresh after nine months (Sharma, 1987).

Maini *et al.* (1983) reported that treatment of Red Delicious apple with calcium chloride 4 per cent for 15 minutes enhanced storage life. Further, the incidence of bitter fruit was reduced from 38.2 per cent in control to 22.4 per cent with post-harvest dip in $Ca(NO_3)_2$ and 20.1 per cent in 4000 ppm daminozide. Waxol coating improved fruit quality and was more effective when combined with alar for storage life improvement up to 60 days, as compared to 30 days under control (Chauhan, 1987).

The poor storage life of scabbed apples and of healthy fruit from infected trees reflect the need to send such fruits to the market for immediate consumption (Gupta and Verma, 1986).

Santa Rosa plum, given a post-harvest dip in 4 per cent calcium chloride for two minutes, recorded the highest colour development and minimum loss in flesh firmness during storage (Chopra *et al.*, 1986).

Packing

Studies conducted on the suitability of different types of packing have shown that the traditional wooden boxes are unsuitable due to the high percentage of bruising (16.6 per cent) and rotting (16.9 per cent) in comparison to imported cartons, which cause bruising and rotting of only 8.5 and 3.5 per cent respectively (Chauhan, 1978).

According to Maini *et al.* (1987), considerable reduction in bruising damage was observed in tray-packed apples during transportation compared with traditional packs. Bruising was reduced from 36 per cent in conventionally packed wooden boxes to 5 per cent in tray packs in wooden or corrugated fibre board cartons (Maini *et al.*, 1984). They further concluded that tray packing is better as it avoids wrapping individual fruits, provides cushioning material, prevents suffocation of the fruit by the proper circulation of air, and dispenses with the services of trained packers to repack these boxes for marketing. The trays can also be recycled.

Processing

Research on processing of apple is very meagre. Technology for apple cider production has been developed at IARI, New Delhi (Ambadan, 1978), while varietal screening has been done by Ambadan (1978) and Nagi Singh and Manjrekar (1976). Methods have been standardized for clarification of juice at CFTRI, Mysore and de-acidification of the juice at RRL, Jammu (Bhatia *et al.* 1979).

Some varieties of apple have been evaluated for processing qualities. Three low-chilling varieties, namely Sharp's Early, Gallia Beauty, and Parlin's Beauty, were found to be more juicy, with a juice content of more than 60 per cent. Pomace of Tropical Beauty registered the maximum pectin content of 9.1 per cent. On the basis of this study, cultivars Tropical Beauty, Sharp's Early, Royal Delicious, and Golden Delicious have been found to be the best for juice processing and pectin extraction from pomace (Gautam *et al.*, 1986).

The technology to develop fermented beverages from apple, plum, peach, and apricot is under standardization. Technology to prepare chuli (wild apricot) wine consists of dilution of the pulp in 1:2 ratio, the addition of DAHP 0.1 per cent, blending clarified wine to give a TSS of 11.5–12 per cent, and maturation in bottles for six months.

Vegetable Research Infrastructure

Research into the improvement of vegetable crops in the region started in 1947–48 in Uttar Pradesh, Himachal Pradesh, and Jammu and Kashmir under ad hoc schemes sponsored by the ICAR. In 1949, the Government of India started the Vegetable Breeding Station at Katrain, located in the heart of the Kulu valley in Himachal Pradesh where a small unit of the Government of Punjab was already operating since 1943. However, systematic research work on seed production and the development of new varieties of temperate vegetable crops was initiated when the Katrain station was transferred to IARI in 1955. At present, work on vegetable research is being carried out by the following organizations:

Himachal Pradesh:	Dr. Y.S. Parmar University of Horticulture and Forestry, Solan
	Himachal Pradesh Krishi Vishwa Vidyalaya, Palampur
Jammu and Kashmir:	Sher-E-Kashmir University of Agriculture and Technology, Srinagar
Uttar Pradesh:	G.B. Pant University of Agriculture and Technology, Pantnagar
	Vivekananda Laboratory for Hill Agriculture, Almora
	Horticultural Research Station, Chaubattia, Almora
Northeast region:	ICAR Research Complex, Shillong

The programme of these institutions is supplemented by the Project Directorate on Vegetable Crops, which has its centres operating at Katrain, Solan, and Srinagar.

In addition, an ad hoc scheme on the control of black rot disease complex of cauliflower is functioning at Dr. Y.S. Parmar University of Horticulture and Forestry, Solan.

Vegetable Research Achievement

Crop Improvement

The germplasm of cabbage and late cauliflower is being maintained at Katrain and Solan. A limited collection of germplasm of garden beet, radish, turnip, and carrot is being maintained at Katrain and Srinagar.

The IARI Regional Station at Katrain has done good work on the standardization of techniques for seed production of different temperate vegetable crops. Subsequently, the priorities changed and emphasis shifted to the breeding of new varieties with varying periods of maturity

and better adaptation to agroclimatic situations. On the basis of these efforts at Katrain and other places, a number of new temperate vegetable varieties have been identified or bred. The important ones are listed in Annex 3.

Crop Production

Temperate vegetables are grown during the winter months in the Indian plains. However, in some pockets, i.e., the hills of Himachal Pradesh, Jammu and Kashmir, and the Uttar Pradesh hills, temperate vegetables are grown during the summer months because of favourable climate and to cater for markets in the plains and increased demand from local markets due to tourist influx. During recent years, off-season vegetable growing has picked up in a big way because of the high value of the produce. In the plains these vegetables are usually the last to come on the market and stay in the field for a considerably longer period of time because they do not throw off their seed stalks as quickly as their tropical and sub-tropical counterparts. The agro-techniques developed for different crops are given below.

CABBAGE

For off-season crops in the hills, successive nursery sowing is recommended from March to July for continuous supply. Delay in planting the variety Golden Acre beyond the end of September may result in reduction of the number of marketable heads (Tewari *et al.*, 1977, Awasthi *et al.*, 1976). The choice of varieties for off-season crops is crucial. Golden Acre and Sel-8 have been found to perform well in this season.

Spacing is dependent upon the cultivars. For early varieties, like Golden Acre, Sel-8, and Pride of India, a spacing of 45× 45 cm between rows and plants is recommended, while for late cultivars where head size is bigger, a wider spacing of 60× 60 cm is desirable. Different NPK doses have been recommended by various workers. Choudhury (1967) recommended 40 to 50 tons of farmyard manure, 325 kg of ammonium sulphate, 270 kg of single superphosphate, and 75 kg of muriate of potash per hectare. Thakur and Gill (1976) reported that 150 kg N, 125 kg P, and 100 kg K is the optimum dose for cabbage. Sharma and Lal (1986) believed that increasing the N level from 60 to 120 kg/hectare results in increased yield.

Seedlings should be watered immediately after transplanting. Thereafter, irrigation at an interval of 7 to 15 days is recommended, depending upon the season, soil, and rainfall. At the time of maturity, watering should be avoided to avoid splitting of the heads. Gautam *et al.* (1976) found that pre-plant application either of Trifulralion (0.51/hectare) or

Basaline (0.51/hectare) ensured excellent control of both dicot and monocot weed species and enhanced yield.

Late Cauliflower

To get a fresh supply of cauliflower during summer and autumn months, periodical sowing of Pusa Himjyoti is recommended, starting from March to June. This has done exceedingly well in areas located at 1000 m above mean sea level (Gill *et al.*, 1987). The raising of the nursery is similar to cabbage. Setbacks even at the nursery stage may result in buttoning. For the main season crop, a spacing of 45× 45 cm between rows and plants is recommended. However, for off-season crops a spacing of 45× 45 cm give better results. From July onwards the sowing of Pure snowball and Pure Snowball k-1 is recommended.

Cauliflower requires very high manuring as it takes large quantities of major nutrients from the soil. For best results, 15 to 20 tons of farm yard manure should be applied three to four weeks before planting. Sixty kg N, 80 kg P, and 40 kg K should be applied just before planting. Another dose of 50–60 kg N may be top-dressed six weeks after planting; 500 kg ammonium sulphate + 187 kg superphosphate is reported to be the optimum dose for the highest yield in Himachal Pradesh. Cauliflower is prone to boron and molybdenum deficiency, for which 10–15 kg/hectare of borax and 1–1.5 kg of sodium molybdate is recommended. Two sprays with 0.3 per cent boric acid before curd formation can also help to correct boron deficiency.

The cauliflower curd should be harvested immediately after it reaches its prime. Late harvesting results in loose, ricey, yellow, and fuzzy curds. Late cauliflower is more susceptible to fluctuations in day and night temperature, which results in a pinkish tinge on the curd.

Knol-khol

Knol-khol is one of the most popular vegetables in Kashmir and can be grown throughout the year by making successive sowings and plantings. For an early crop in the northern hills, sowing is done in March-April according to the altitude, with some protection at night. For an off-season crop, spacing of 30 × 15 to 20 cm is recommended, while in the main season (winter sowing), the spacing should be more. Knol-khol requires steady growth and any check in growth will make the knobs fibrous. Best yields are obtained with 75 to 100 kg N and 60 kg P.

Carrot

Temperate variety carrots are more popular in the hills as these contain much higher carotene content than their asiatic counterpart. In the higher hills (1200 m above mean sea level), carrot can be grown

throughout the year barring a few winter months (November to March). However, in the foothills, carrots are grown from August to November. The seeds are sown on ridges about 15 cm deep.

Well-rotted farmyard manure should be applied at the rate of about 30 tons/hectare, which should be supplemented with 60 kg N and 50 kg each of P and K (Choudhary, 1976).

RADISH

Radish is very useful for intercrop or companion planting between rows of crops of slower growth. By choosing the appropriate varieties, radish can be grown throughout the year in the hills as well as the plains. For the higher hills, Pusa Himani is most successful for growing from March to June, Japanese White from July to September, and Pusa Rashmi from October to November. For table purposes, Rapid Red, White Tipped, and White Icicle are the best varieties.

TURNIP

Turnip is grown on a very limited area during the main season. It is sown from August to November, depending upon the altitude. In the higher hills, sowing from March to May gives the best results, while in the lower hills, the best sowing time is from August to September. In heavy soil, sowing on ridges at a distance of 40 cm from each other is recommended. However, in sandy loam soil, flat sowing gives an equally good result. The fertilizer dose recommended is 20 to 25 tons of well-rotted farmyard manure, which should be supplemented with 60–70 kg N and 50 kg each of P and K per hectare (Choudhary, 1967).

OTHER VEGETABLES

Brussels sprouts and heading broccoli, which also belong to the cole group of crops, are not commonly grown in India. However, their cultivation is slowly picking up due to increased demand from large hotels catering to foreign tourists. The cultivation of brussels sprouts is similar to cabbage. No research has been done in India on this crop because of its minor importance.

Seed Production in Different Vegetable Crops

The Kashmir valley specializes in the seed production of cabbage, knolkhol, turnip, carrot, and garden beet, while Saproon valley and other adjoining areas of Solan in Himachal Pradesh concentrate on seed production of late cauliflower and some radish varieties. Seed production in the western Uttar Pradesh hills has also picked up quite recently. In these regions, most of the crops are planted for seed in August-September,

passing through the vegetative phase during the snowy winter months of December-February, and flower after overwintering late in spring, producing seeds from April to June. Seed production in cabbage, cauliflower, and turnip is described below:

There are three main methods of seed raising in cabbage, namely, seed to seed, head to seed and late planting. Head to seed method is most suited for seed production of cabbage. To maintain the genetic purity of the crop roguing is essential, which should be accomplished before plants are stripped for their outer leaves in the months of November and December. An isolation distance of 1 km, between two varieties or sub-species of *B. oleracea* for certified seed is recommended. However, for breeder's seed, the distance should be more, preferably 1600 metres.

Most of the cultivated types of cabbage are biennial in nature. So far no variety has been bred which can produce satisfactory seeds in the plains.

The sowing and transplanting of the varieties should be so adjusted that head formation is complete before the onset of winter (November), by which time the temperature falls below 10°C, which causes wintering of mature heads. It has been seen that the Drum Head type should be sown in a nursery in the third week of June and transplanted by the first week of August. In a late-sown crop, head formation will take place after winter with no seed stalk formation. A mean temperature of 22°C, 20°C, and 15°C during the months of August, September, and October respectively is best for growth and head formation. Early varieties, like Golden Acre and Pride of India, should be sown from 10 to 25 July and transplanted during the second fortnight of August.

The highest seed yield can be realized by applying 250 kg each of N and P_2O_5 and 100 kg of P per hectare (Thakur and Gill, 1976). In case the growth of the crop is below normal, 2 per cent urea spray at 10-day intervals is very helpful to boost growth.

Crop Protection

PESTS

Among insect pests, cabbage white butterfly (*Pieris brassicae*) and aphids (*Brevicoryne brassicae*) are the two major pests of cabbage. Cabbage butterfly makes its appearance during the month of March when bright yellow eggs are laid usually in clusters on the leaves. On hatching, the young green caterpillar feeds on the surface of the leaves and skeletonizes them, but as the pests grow they crawl to all parts of the plant. In case of heavy infestation all the plant parts, including the pods of the seed crop, are completely destroyed, drying the attacked shoots. The pest remains active up to June and reappears in August-September. Spraying

with 0.2 per cent Sevin gives some control. The attack by cabbage aphid and mustard aphid persists throughout the year in brassica crops, even during winter when covered with snow. The cloudy season accompanied by high humidity from March onward is very favourable to pest multiplication. Aphids can be successfully controlled by 0.03 per cent spray of dimecron in the vegetative stage and 0.2 per cent spray with thiodan or sumithion in the flowering stage, as they are safe insecticides for bees, which visit the flowers and help in pollination.

Besides the cabbage caterpillar and aphid, thrips (*Thrip tabaci*) cause considerable damage to turnip and radish crops. The presence of thrips in small numbers helps in pollination, but in case of heavy infestation, the flowers become sickly and setting is affected. Spraying with thiodan (0.2 per cent) or sumithion will help to keep the thrip population in check. Besides controlling thrip, these sprays will also help to control caterpillars and aphids, which can be quite serious at this stage.

Radish may be attacked by aphid at the seedling stage and can be checked by 0.2 per cent spray with malathion or any other insecticide. Sometimes, leaves are attacked by cabbage caterpillars, which can also be controlled by 0.2 per cent spray with malathion.

Diseases

The most serious disease of cole crops at the nursery stage is damping off caused by *Pythium* and *Rhizoctonia* sp. To get rid of these soil-borne diseases, the nursery beds should be treated with 2–3 per cent formaldehyde (1 part in 48 parts of water). Well-prepared nursery beds should be thoroughly drenched and covered with a sheet of alkathene to prevent escape of the fumes for 96 hours. Before sowing the seeds, the nursery beds should be kept open for at least 48 hours. Seed treatment with 0.3 per cent Bavistin or Difolatan or Captan will help to get rid of seed-borne fungal diseases. Five litres of solution is sufficient for one sq.m.

Rhizoctonia is caused by *Rhizoctonia solani* and may attack at different stages of plant growth. Young, transplanted seedlings of cole crops suffer the most. Drenching the soil around the plants with 0.3 per cent Brassiocol or Captan is helpful to combat this disease. High temperature accompanied by high soil moisture favours the spread of infection.

Black rot is a bacterial disease caused by *Xanthomonas campestris*. The disease is very common in off-season crops of cabbage and cauliflower in the northern hills.

Late Cauliflower

Techniques for seed production of late cauliflower have been standardized at Katrain. The seeds of early varieties of cauliflower have been produced in the country for a long time, but it has been possible to pro-

duce the seeds of late cauliflower since 1958 (Singh *et al.* 1960). The seed production of late cauliflower is limited to temperate regions, like Kulu valley and Saproon Valley of Himachal Pradesh, U.P. hills and Jammu region of J & K. The late cauliflower differs from other temperate vegetables in that it requires no wintering to break its dormancy. The success or failure of the late cauliflower seed crop depends mainly upon the time of transplanting which should be so adjusted that curd formation takes place when there is no danger of frost or snow. Experiments conducted at Katrain have revealed that the last week of August is the best time to sow the nursery and the first and second weeks of October for transplanting under Kulu and Saproon Valley (Solan) conditions where the bulk of cauliflower seeds are produced. Cauliflower is a very sensitive crop and even a little fluctuation in environmental factors can affect the crop seriously.

Heavy rainfall and even a little snowfall in the month of February are very harmful. However, better and assured seed yield can be obtained at a slightly lower elevation (1200 to 1450 m) where temperature fluctuations are not so wide. Relative humidity was not found to play any part in cauliflower seed production (Gill and Singh 1974).

Turnip

There are two distinct groups of turnip from the seed production point of view, namely asiatic and temperate. Asiatic types easily set seed in the plains. Therefore, the seeds of asiatic varieties can more profitably be produced in the plains. The seeds of temperate types are produced in the temperate hilly regions of the country, Kashmir Valley, Kulu Valley and Kalpa district of Himachal Pradesh. The crop is biennial in nature. For the temperate type seed sowing is done by the end of August or beginning of September and roots are ready by November. There are two methods of raising the seed of turnip i.e., seed to seed and root to seed. In the seed to seed method, the selection of roots is not possible and if the stock seeds are not of very high quality there are chances of great deterioration of the variety. Therefore, the root to seed method is advisable, although the yield of seed obtained by the seed to seed method is much higher. To raise stock seed the root to seed method is always followed. For certified seed production, an isolation distance of 1000 metres between any two varieties is necessary. However, for the production of foundation seed the distance should be more, preferably 1600 metres. Turnip should also be equally well isolated from mustard, Chinese cabbage, rutabaga and rape.

The seed crop usually ripens in the second fortnight of May. Due to easy dehiscence, turnip pods when fully dried shatter very easily. It is, therefore, advisable to cut the turnip crop when 60 to 70 per cent of

the pods have turned yellowish brown. Harvesting in the early hours is recommended to avoid shattering. There are no control measures except to breed and grow resistant varieties. Two resistant varieties, one each in cabbage (Pusa Mukta) and cauliflower (Pusa Shubra), have been released by IARI. Some precautionary measures are also helpful in containing the disease, which is normally soil as well as seed-borne. Three-year rotations with non-cruciferous crops and hot water treatment of seed at 50°C for 30 minutes before sowing have been recommended as control measures.

Potato Research Infrastructure

Potato research is being carried out exclusively by two organizations, the Central Potato Research Institute, Shimla (CPRI), and the All India Co-ordinated Potato Improvement Project (AICPIP). Both organizations are under the ICAR and have their headquarters at Shimla (Himachal Pradesh). Whereas CPRI is primarily engaged in developing crop production, the AICPIP is engaged in testing newly developed varieties and techniques at various locations and assessing their suitability for adoption. The AICPIP centres are located at the state agriculture universities, which provide infrastructural facilities for conducting research work. The region has the following CPRI stations and AICPIP centres:

- CPRI, Shimla; established 1935/1945
- CPRI Research Station, Kufri-Fagu (Himachal Pradesh), established 1935/1968
- CPRI Research Station, Mukteswar (Uttar Pradesh), established 1975
- AICPIP headquarters, CPRI, Shimla, established 1971
- AICPIP Sub-centre, HPKVV, Palampur (Himachal Pradesh), established 1975
- AICPIP Main centre, SKUAST, Shalimar, Srinagar (Jammu and Kashmir), established 1972

Of these, the stations at Kufri-Fagu and Mukteswar are potato seed-producing centres, whereas the CPRI, Shimla and AICPIP centres at Palampur and Srinagar are involved in conducting research on potato.

Potato Research Achievements

Crop Improvement

Germplasm Collection

Efforts have been made to collect the old potato varieties being cultivated in the region. The first collections were made in the early 1940s

through the Department of Agriculture and Marketing Department. As many as 50 samples were collected from Himachal Pradesh (Pushkarnath, 1969). Among the varieties collected were Magnum bonum, Sathoo, Up-to-Date, and Darjeeling Red Round from Himachal Pradesh, Italian White Round, Up-to-Date, Chamba Red, Sathoo, Gola C, Phulwa, and Darjeeling Red Round from Jammu and Kashmir and Magnum bonum, Gola, Majestic, Up-to-Date, Dunbar Cavalier, Darjeeling Red Round, and President from the Uttar Pradesh hills. Since 1985, CPRI has undertaken a systematic survey of remote areas to collect old potato varieties. The details of these surveys are given here under in Table 10.2: This material forms a part of the potato germplasm collection at CPRI and is being used in variety improvement programmes. More surveys to collect additional indigenous varieties from the north western Himalayan region have been planned in the next few years.

TABLE 10.2

Potato varieties cultivated in the northwest Himalaya region

Date of collection	State	District	No. of samples collected
November 20–24, 1985	UP	Uttarkashi	16
August 25 to September 5, 1986	HP	Shimla	41
October 16 to November 6, 1988	HP	Shimla	12
		Kinnaur	37
	UP	Uttarkashi	6

VARIETY IMPROVEMENT

Work on potato variety improvement began in 1935 with the establishment of the Potato Breeding Station at Shimla. In 1949, a disease-free clone of Up-to-Date from Northern Ireland was released by the CPRI in Himachal Pradesh. Subsequently, the variety Craigs Defiance was introduced from the United Kingdom. Later, three potato varieties, Kufri Kumar, Kufri Kundan, and Kufri Jyoti, bred at CPRI were released during 1958 and 1968.

Ever since its release, Kufri Jyoti has continued to be the most popular variety in the region, because of its high yielding ability and resistance to late blight. However, in the last few years this variety has started getting late blight infection due to a change in the racial pattern of *Phytophthora infestans*, the organism that causes late blight. Efforts are, therefore, being made to select a culture possessing a high degree of field resistance to late blight and good yield. A large number of such cultures are being tried at Shimla/Kufri, Palampur, Ranichauri (Uttar Pradesh), and Srinagar centres of CPRI and AICPIP.

Crop Production

A large number of experiments have been conducted on various aspects of crop production in this region. Some of the data have been published and a lot more is available in the annual progress reports of CPRI and AICPIP. The major findings are given below:

NUTRITION

Fertilizer application is needed to meet the nutrient requirements of potato in most of the soils of the region. The optimum fertilizer dose varies with soil type, variety, climate, cropping pattern, composition of fertilizers, and the time and method of application.

A good crop of potato removes about 120 kg N per hectare from the acidic brown hill soil. The peak period of N uptake is from 60 to 80 days in the hills. The economic potato response to hill soil in Himachal Pradesh and Jammu and Kashmir is up to 92 kg N/ha (Grewal and Sharma, 1980). The dose of nitrogen in valleys may vary from 100-150 kg/ha. Economy in the dose of N can be affected if farm yard manure is applied 25-30 t/ha (Grewal and Sharma, 1981). Urea as source of N is comparatively less efficient than ammonium sulphate, ammonium chloride and calcium ammonium nitrate. A dose of urea higher than 40 kg N/ha adversely affects germination (Sharma and Grewal, 1978). The broadcasting of N fertilizer does not ensure its proper utilization by the potato plant. Grewal *et al.* (1979) reported that the placement of N fertilizer either in furrows or in side bands is significantly superior to 104 and 120 kg N/ha for furrow placement, band placement and broadcasting methods respectively. Split applications of N dose is recommended to avoid the deleterious effect a higher N dose has on seed tuber emergence. Thus, half the N dose should be given before planting and the rest by spraying around the time of tuber initiation (Sharma and Grewal, 1978) or 2/3 at the time of planting and 1/3 at earthing up (Grewal *et al.* 1979). If the second dose of N is to be given as a spray application of urea, the concentration of urea in the spray solution should not exceed 2.0 per cent and the biuret in urea should be less than 0.5 per cent (Sharma *et al.* 1975).

The deficiency of phosphorus is more pronounced in acidic hill soil as this is characterized by high P fixation capacity. The optimum P dose for this soil is 57 kg/ha. A number of phosphatic fertilizers have been tested for their efficacy. In the acidic soil of Kangra (HP) the relative efficiency of superphosphate, multiphosphate, defluorinated phosphate, fused magnesium phosphate, rock phosphate and a mixture of rock phosphate and superphosphate was 100,83.3, 88.7, 74.6, 61.6, to 83.9 and 95.3 respectively (Randhawa *et al.* 1968). Water soluble P fertilizers, particularly superphosphate, is the most suitable for potato in the hill soil of Shimla

region (Sharma *et al.* 1976 a). P fertilizer should be placed near the active root zone of the plant. Verma and Grewal (1978) and Grewal and Verma (1982) reported that the placement of P fertilizer in furrows is better than broadcasting and band placement. The optimum P dose was calculated to be 52 kg/ha through broadcasting and band placement and 41 kg/ha through furrow placement. For the efficient use of P fertilizer, potato seed tubers should be soaked in 1.5 per cent single superphosphate solution. This treatment economises P use by 22 kg/ha (Sharma *et al.*, 1984).

The potato's need for potassium is high. On average, it removes about 190 kg/ha from acidic brown hill soil (Sharma *et al.* 1978). The peak period of K uptake is generally 60–80 days under the long day conditions in the hills which coincide with the tuber development phase (Sharma *et al.*, 1978). K application generally increases the size of the tubers which results in higher tuber yield. The optimum K dose for hill soil is 93 kg/ha (Grewal and Sharma, 1980). Potato varieties differ greatly in their response with K application. Among the various sources of K, potassium sulphate is found to be more efficient than potassium chloride and schoenite (K_2SO_4 + $MgSO_4$) in acidic hill soil (Sharma *et al.*, 1976). Furrow placement of K is the most efficient and economical method of application to potato (Grewal and Verma, 1982). Application of farm yard manure 30 t/ha can meet the P&K requirement of potato crop and can also economize on N dosage.

Positive response to copper, iron, boron and molybdenum has been observed in experiments conducted at Shopian (J&K) and to zinc at Shimla (Grewal and Trehan, 1979). Field experiments conducted at Shimla (Trehan and Grewal, 1981), revealed that soaking seed tubers in 0.05 per cent zinc sulphate solution for 3 hours or dip treatment of seed tubers in 2 per cent zinc oxide suspension were efficient and economical methods to meet the zinc requirement of potato.

Irrigation

The potato crop grown in the hills is mostly rainfed. Although the total annual precipitation in the hill regions may exceed evapotranspiration, there is moisture deficiency in early summer and excess water in the monsoon season. The use of a vegetative mulch in the pre-monsoon period conserves soil moisture and increases the tuber yield (Singh *et al.* 1975). Water harvesting within the field is also a good practice in areas receiving some pre-monsoon showers.

Weed Control

The dominant weeds found in potato fields in the northwestern hills are *Oxalis latifolia, Galinsoga parviflora, Echinochloa colonum,*

and *Setaria glauca*. Nankar and Singh (1982) reported that the nutrient losses caused by weeds at Shimla amounted to 42.6 kg N, 8.24 kg P, and 48.5 kg K/hectare. In an experiment with weed control through cultural practices and weedicides, the cultural treatment (hand weeding 50 days after planting) was found to be the best. It saved the nutrients by 33.5 kg N, 6.3 kg P, and 37.6 kg K/hectare. Among the weedicides, treatment with EPTC (3.75 kg ai per hectare, pre-planting) + Linuron (0.25 kg ai per hectare, pre-emergence) + Propanil (0.87 kg ai per hectare, post-emergence) was the best in controlling weed flora.

Seed Production

Traditional potato seed production involves identification of virus-free seeds and its multiplication (usually in three years) to produce breeder's seed stocks. To date, the detection of viruses in tubers was done by serological techniques. However, a more efficient technique, ELISA (enzyme-linked immuno sorband assay), has recently been introduced into the Indian potato seed production programme for the detection of viruses PVX, PVS, and PVY. Virus detection with this technique is nearly 20 times more efficient than by serological testing. The virus-free or indexed tubers are subsequently multiplied by tuber cutting and also by sprouts.

Efforts are also being made to micropropagate indexed tubers to produce *in vitro* microtuberlets.

Crop Protection

Pests

The soil pests commonly infesting potato are cutworms and white grubs, but the former are more destructive. Five species of cutworms—*Agrotis ipsilon*, *A. interacta*, *A. flammatra*, *A. spinnifera*, and *A. segetum*,—damage crops in India (Saxena, 1977). Of these, *A. segetum* and *A. ipsilon* are more important in the hills.

Cutworms occur regularly in the early period of crop growth (May-June) when the weather remains dry. Control of cutworms is possible by drenching the ridges with chlorpyriphos 20 EC at 2.5 l/hectare in 1000–1250 l when water 75 per cent of plants have emerged.

White grubs are usually present in all types of soil throughout the year in hilly tracts. They are, however, serious only occasionally and only in pockets. They feed on the underground tubers, making them unsuitable for marketing. This can be controlled by the application of Phorate 10 G or Carbofuran/3 G at 2.5 kg ai./hectare at earthing up (Anon., 1988).

Aphids (*Myzus persicae*) are important mainly because they are vectors of potato virus diseases which cause degeneration of seed stocks. In the northwestern hills, the aphid population generally remains below the critical level during the summer crop season. The critical limit is crossed only by the end of July. In the Uttar Pradesh hills, aphids generally cross the critical limit by early June. Insecticides like phorate (Thimet 10, G) at 10–15 kg/hectare in the furrows at the time of planting supplemented by foliar spray with oxydementon-methyl (Metasystox 25 EC) or dimethoate (Rogor 30 EC) at 1.2 l and 800 ml respectively, in 1125 l water for one hectare, provide good protection to the crop (Misra and Raj, 1977).

Diseases

A total of 24 diseases of potato have been recorded (Shekhawat, 1988) in the hills of Himachal Pradesh. Several of these are found in the hill districts of Uttar Pradesh and Jammu and Kashmir.

Late blight is the most important disease in the entire northwestern hill region. The disease generally appears during the first week of July and kills susceptible varieties by mid-August. Losses due to the disease range from 21 to 74 per cent.

Several fungicides—mancozeb, copper oxychloride, oxadixyl, and matalaxyl formulations—are available for the control of the disease. Of these, mancozeb at 2 kg/hectare is commonly used. Continuous use of a single fungicide can result in selective depletion of beneficial soil microflora (Shekhawat, 1988). It is, therefore, desirable to use alternative or sequential sprays of one or more fungicides. To enable the farmer to prepare for timely spray of fungicides, a late blight forecasting system has been developed (Bhattacharyya *et al.*, 1982).

The main source of inoculum for disease development is the infected seed tuber. Proper earthing up of tubers and preventing the build-up of foliar inoculum by fungicidal spray and by haulm cutting when 20 per cent of the foliar infection is observed helps to reduce tuber infection.

The soil- and tuber-borne diseases—common scab, black scurf, and powdery scab—do not reduce yield but lower the market value of the produce. These diseases are increasing in many areas because of monoculture of potato. (Singh and Nand, 1988). Control measures for these diseases include: treatment of seed tubers to eradicate seed-borne inoculum by dipping tubers in 0.5 per cent organomercurial compound or in 3 per cent boric acid (pharmaceutical grade) for 30 minutes within 45 days of harvest; crop rotation with cereals, millet, or maize; and ploughing the land immediately after harvest so that it is exposed to low winter temperatures.

Brown rot of potato is a widespread disease in Kumaon hills (Singh, 1977) and several districts of Himachal Pradesh (Shekhawat, 1988). The disease is primarily seed-borne and the pathogen may remain viable in

infested fields for two or three years. There are no resistant varieties available for commercial cultivation in India. Hence, cultural practices have been developed to contain this disease: use of disease-free seed; application of stable bleaching powder at 12 kg/hectare along with fertilizer in furrows at the time of planting; and growing potato in three-year rotations with maize, cereals and onion (Shekhawat, 1988).

Future Thrusts

The above review clearly indicates that systematic efforts have been made to create suitable infrastructure for research on temperate fruits and vegetables, including potato, in the Himalayan region of India. Further sound research programmes have already been initiated to tackle various aspects of crop improvement, crop production, crop protection, and to a lesser extent post-harvest management by various institutes and universities. This has resulted in building up valuable indigenous and exotic germplasm, identification of varieties for different regions, and the release of new varieties particularly of apple, vegetables, and potato. Several long-range trials to standardize agro-techniques have been laid out, particularly in fruit crops. However, the problems facing the fruit and vegetable industry are diverse and require concerted efforts to solve them. Some of the areas identified for this purpose are given below:

Fruit Crops

Emphasis needs to be given to the introduction of new germplasm, particularly new spur-bearing scion cultivars of apple, mutant selections of Delicious which develop better red fruit colour even in conditions of shade within the tree canopy, and new apple rootstock and new cultivars of cherry, peach, almond, and walnut developed in the United States and Europe.

Selections of the apple cultivar Delicious are notoriously unstable and mutate quite frequently. Efforts should be made to select improved, possibly compact 'sports' from existing orchards. Similarly, clonal selection may be made of walnut and almond having adaptability to particular environments and ease of propagation. Selection of suitable clonal rootstock out of different *Malus* species with semi-dwarfing vigour, tolerance to drought or adverse soil and moisture conditions, and resistance to root rot, collar rot, and woolly aphid may be made.

Cultivars resistant or tolerant to apple scab, powdery mildew, and woolly aphid need to be evolved through breeding.

The role of pollinizers and pollinators, including honey bees and other insects, needs to be fully assessed to improve fruit set. This should also

take into consideration the female sterility prevailing in the Delicious group of apples.

In vitro micropropagation technique may be employed for the distribution of new and/or virus-free germplasm. Efforts should be to supply virus-free planting material from elite nurseries in large quantity.

For flat areas the optimum density for high-density planting needs to be determined and suitable systems of training and pruning defined.

Standardization of macro- and micro-nutrient requirements for young and bearing trees, doses of fertilizer for trees with different crop loads, and time and method of application need to be standardized.

Drip irrigation has high potential to increase fruit production through conservation and management of scarce water resources in rainfed areas. This system of irrigation may be tried for cultivation of temperate fruits.

Productivity of apple (tons/hectare) in Himachal Pradesh, Jammu and Kashmir, and Uttar Pradesh is significantly lower than in Europe or the Unites States. The best production figures noted in Jammu and Kashmir were only 50 per cent of those expected in most parts of northern Europe. Orchard productivity can only be maximized if an efficient tree spacing, pruning and training system is adopted. This involves optimal integration between tree spacing and appropriate techniques of branch and central leader pruning and training.

Suitable areas for apple and other temperate fruits need to be delineated on the basis of chilling hours, freedom from spring frost, hail, rainfall, and other factors.

A system of orchard soil management suitable for slopes and level areas needs to be worked out to conserve soil moisture and nutrients. Studies should also be conducted on replanting problems or soil sickness in apple orchards.

Intensive research into the effect of spring frost, hailstorms, and fluctuating temperature at the time of flowering and fruit set needs to be undertaken under different agroclimatic conditions. This should also include the use of growth regulators to delay flowering in order to escape frost damage and to ensure better fruit set under adverse weather conditions.

The extent of alternative bearing by different cultivars should be assessed and suitable remedial measures, including blossom thinning during the 'on year' with the help of growth regulators, should be worked out.

Economical methods of control need to be worked out against apple scab, powdery mildew, root rot, collar rot, canker complex, San Jose scale, woolly aphid, defoliating beetles, and other pests and diseases. An apple scab disease prediction control system with the minimum number of sprays needs to be based on weather and inoculum parameters.

Integrated pest management employing biological control agents for temperate fruits, particularly apple, should be standardized.

The problem of codling moth in the Ladakh area of Jammu and Kashmir should be taken up on a priority basis. Quarantine measures should be introduced to check its spread to other areas.

Reliable maturity standards for apple need to be worked out for the fresh market and for fruit to be stored or processed. Grading by quality and colour needs to be improved and standardized. Packing methods must be improved to avoid bruising and injury during handling and transport. Alternative packing cases other than wood have to be developed and their suitability and economics determined.

On-farm air cool storage and cold storage is necessary in the production areas to regulate supply and avoid gluts.

Suitable cold storage, controlled atmosphere storage, and hypobaric storage needs to be tried on an experimental scale and the optimum temperature and relative humidity for storage of different cultivars determined to ensure their availability to the consumer in good condition over a prolonged period.

At present, only apple juice is manufactured in the country. Some diversification in processed products is required like apple chips or crisps, alcoholic beverages such as cider, or cherry, apricot, peach, or strawberry nectar. In Europe and the United States, fruit-based carbonated drinks are becoming very popular and they should be introduced in India.

Some basic research should be carried out on crop and growth manipulation, including plant growth regulators.

Apple is currently the dominant temperate fruit crop produced in the country. There is a need to diversify into pear, cherry, peach, apricot, nectarine, olive, hops, saffron, figs, and plum. More emphasis should be given to the cultivation of nuts, particularly almond, walnut, pecan, and pistachio. The economics of apple farming alone and with pear, cherry, almond, or vegetables needs to be worked out to find suitable combinations.

The wide gap between the technology now available and its actual application by farmers should be bridged immediately through reorganization and strengthening of the departments of horticulture in hill states, so that they can provide competent professional horticultural extension services.

For quick adoption of horticultural technologies at the farmer's level, demonstrations should be arranged on orchard management, tree canopy management, density of plantation, moisture conservation, *in situ* tree nutrition, integrated pest and disease management, and other such aspects in accordance with the requirements of the area.

A national variety foundation (elite progeny orchard) should be established as a repository of all commercially grown varieties in the three hill states to serve as a scion bank.

The data base of horticultural crops is inadequate and, in some cases, not reliable. The data base, particularly area, production, and yield of different crops, should be regularly compiled. Crop cutting experiments on important tree crops should be initiated. The impact of tree crops on ecology and the environment must also be quantified.

Vegetable Crops

There are several constraints to the production of vegetables in the northwestern hills. These include moisture stress, acidic soil, and nutrient fixation, besides some major diseases and insect pests. The major diseases of cole crops are damping off caused by *Pythium* and *Rhizoctonia* spp., downy mildew caused by *Paranospora parasitica*, black rot (*Xanthomonas campestris*) in commercial crops, and cabbage yellowing (*Fusarium oxysporum f. conglutinans*), bacterial soft rot (*Erwinia carptovora*) in seed crops. In the root crops, root rot (*Fusarium oxysporum*), white rust (*Cystopus*), and Phyllody are important diseases. Among the insect pests, cabbage white butterfly (*Pieris brassicae*), aphids, and thrips are serious. Only limited information on the management of acidic soil, water management practices, and nutrient fixation is available. Ways to resist most of the diseases of these crops, except black rot in cauliflower and cabbage, are not known.

The following objectives have been identified to improve vegetable production in the region:

- Development of varieties possessing resistance to major diseases and insect pests, particularly curd rot and alternaris blight of cauliflower, adaptable to wider areas
- Development of F_1 hybrids in cabbage, cauliflower, radish, and turnip
- Intensification of research on seed production and location of new disease-free seed production areas
- Vegetable-based cropping systems and a package of agro-techniques for improved varieties
- Development of varieties for stress environment (e.g., drought, acid soil)
- Integrated management of common diseases and insect pests.

In addition, timely supply of essential inputs such as, quality seed, balanced mixtures of fertilizers, and plant protection chemicals and the organization of efficient marketing of the produce will go a long way towards boosting the production of vegetables in this region.

There are several major constraints to potato cultivation in the northwestern hills. These include moisture stress during the early phase of crop growth and excess moisture during the tuberization phase, high fixation of nutrients in acidic hill soil, and incidence of late blight and,

to some extent, bacterial wilt or brown rot diseases. However, there are several constraints to tackling these problems, namely, inadequate information on water and soil management practices; insufficient information on reducing nutrient fixation, especially P and K in acidic hill soil; and the non-availability of sources of resistance to brown rot so as to develop resistant varieties.

The following objectives have been identified to improve potato production in the region:

- Development of late blight-resistant varieties to replace the new susceptible variety Kufri Jyoti
- Evaluation and development of soil management practices for water optimization and conservation in relation to potato crop
- Development of a potato-based cropping system for efficient use of nutrients and to reduce the incidence of soil for tuber-borne diseases
- Management of brown rot.

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Annex 1

Promising cultivars of fruits identified in Himachal Pradesh

Apple Spur Type:	Red Spur, Golden Spur, Stark Spur, Orgon Spur, Miller Sturdy Spur, Starkrimson
Colour mutants:	Top Red, Royal Red, Vance Delicious, Hardeman
Low-chilling:	Tropical Beauty, Parlin's early Worcester
Peach, for mid-hills:	Shimizu Hakuto, Kanto-5, and Dawne
For valley areas:	Early Amber
Plum:	Greenage, Simmon, Frontier, Queen Ann Nubiana, Friar
Apricot:	Farming Dale, Local selection
Almond:	Merced, White Brandis, Kashmir Seedling, Star Basin
Kiwi fruit:	Allision, Hayward
Olive, pickle type:	Aglandeau, Frantoio, Ascoiternana, Leccino, Coratina
Oil type:	Ascolano, Grosseune, Cornicobra, Itrana, Mission

Annex 2

Recommended spray schedule for the control of apple scab disease (Agrawala 1985)

Tree stage	Schedule	Amount (chemical/100 l water)
Silver tip to green tip	Difolatan (SALT),	300 g
	Difolatan,	200 g
	Captan 75 WP, or	300 g
	Dithane M-45	400 g
Pink bud or after 15 days	Dithane M-45,	300 g
	Captan 50 WP, or	300 g
	Captan 75 WP	200 g
Petal fall	Carbendazim (Bavistin, B-stein, MBC-JK-stein, or Agrozim)	50 g
Fruit set (10 days after petal fall)	Dithane M-45,	300 g
	Captan 75 WP,	200 g
	Captan 50 WP, or	300 g
	Mixture of Carbendazim and Dithane M-45	250 g
Fruit development (14 days after fruit set)	Dithane M-45,	300 g
	Delan,	50 g
	Captan 50 WP, or	300 g
	Difolatan	150 g
14 days later	Repeat only Dithane M-45, or Delan or Captan 50 WP	
Pre-harvest	Repeat Dithane M-45, Delan, Captan 50 WP	
Pre-leaf fall	Urea	5 kg

Annex 3

Important Vegetable varieties identified or bred in the hill region

Crop	Name of variety	Institution	Remarks
Cabbage	Golden Acre	IARI research Station, Katrain	Introduction
	Pusa Mukta (Sel - 8)	IARI research Station, Katrain	By hybridization. Resistant to black rot.
	Pusa Drum Head	IARI research Station, Katrain	Selection field-resistant to black leg.
	Pride of India	Dr. Y.S. Parmar University of Horticulture and Forestry	Introduction.
	September	Tamil Nadu Agricultural University	Introduction suitable for Nilgiris.
Late cauliflower	Pusa Snowball-I	IARI Regional Station, Katrain	Hybridization.
	Pusa Snowball-I	IARI Research Station, Katrain	Selection.
	Pusa Snowball-I	IARI Research Station, Katrain	By inbreeding and selection.
	Pusa Himjyoti	IARI Research Station, Katrain	Selection from III maturity group.
Knol-khol	White Vienna	IARI Research Station, Katrain	Introduction.
	Purple Vienna	IARI Research Station, Katrain	Introduction.
Brussels sprout	Held Ideals	IARI Research Station, Katrain	Selection.
Garden beet	Detroit Dark Red	IARI Research Station, Katrain	Introduction.
	Crimson Globe	IARI Research Station, Katrain	Introduction.
Carrot	Nantes	IARI Research Station, Katrain	Introduction.
	Pusa Yamdagni	IARI Research Station, Katrain	Selection.
	Zeno	Tamil Nadu Agricultural University	Suitable for Nilgiri hills.