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REVIEW ARTICLE

Current Status and Potential of Temperate Fruit Crops for Livelihood and Nutritional Security in India

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Abstract

The horticultural sector in India has emerged as a formidable force in global production, with the nation claiming the position of the second-largest producer worldwide. In the fiscal year 2022-23, India's horticultural output reached an estimated 351.92 million tons, showcasing a notable increase of approximately 4.74 million tons (1.37%) compared to the preceding year. Fruit crops, a significant component of this sector globally, span an extensive area of approximately 68.05 million hectares, yielding a staggering 867.77 million metric tons annually, averaging 12.75 tons per hectare. India's contribution to this domain is notable, with fruit production totaling around 107.51 million metric tons, cultivated across 7.06 million hectares, boasting an average productivity of 15.22 tons per hectare. The Indian Himalayan region stands out as a promising landscape for the cultivation of temperate horticultural crops, including fruits, vegetables, ornamental plants, and medicinal and aromatic species. Encompassing latitudes 26°20' to 35°40' N and longitudes 74°50' to 95°40' E, this region spans from the foothills in the south (Siwalik's) to the Tibetan plateau in the north (trans-Himalaya), comprising approximately 95 districts of the country. Despite its fragile terrain, characterized by snow-clad peaks and dense forests, the Indian Himalayas contribute significantly, covering 16.2% of India's total geographical area. Temperate fruit cultivation thrives predominantly in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh, capitalizing on the region's climatic advantages. Notably, a diverse range of temperate fruits such as apple, pear, peach, plum, apricot, cherry, almond, and walnut flourish in this region. With its relative climatic advantages and conducive environmental conditions, the Indian Himalayan region continues to serve as a vital hub for the production of temperate fruits, underscoring its significance in India's horticultural landscape.

Keywords: Current status, India, Livelihood, Nutritional security, Temperate fruit crops.

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Introduction

The Indian Himalayan region emerges as a promising landscape for the cultivation of temperate horticultural crops, encompassing a diverse array of fruits, vegetables, ornamental plants, and medicinal and aromatic species. Spanning latitudes 26°20' to 35°40' N and longitudes 74°50' to 95°40' E, this region extends from the foothills in the south (*Siwalik's*) to the Tibetan plateau in the north (trans-Himalaya), encompassing approximately 95 districts of the country. Despite its fragile terrain, characterized by snow-clad peaks and dense forests, the Indian Himalayas significantly contribute, covering 16.2% of India's total geographical area. Temperate fruit cultivation thrives predominantly in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh, capitalizing on the region's climatic advantages (Ahmad *et al*., 2021; Mitra and Roy, 2013). Notably, a diverse range of temperate fruits such as apple, pear, peach, plum, apricot, cherry, almond, and walnut flourish in this region. With its relative climatic advantages and conducive environmental conditions, the Indian Himalayan region continues to serve as a vital hub for the production of temperate fruits, underscoring its significance in India's horticultural landscape (Verma *et al.,* 2010; 2013; 2023). India's production of temperate

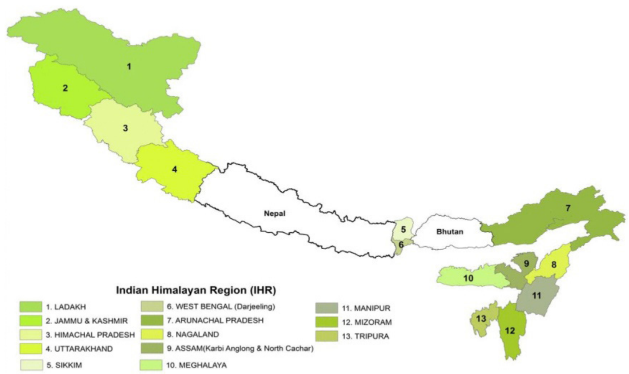

Figure 1: Temperate fruit-growing states in the Indian Himalayan region

Table 1: List of temperate fruit crops grown and suitable for commercial cultivation.

Group	*Fruit crops*
Pome fruits	Apple, pear, quince
Stone fruits	Peach, nectarine, plum, prune, plumcot, apricot, sweet cherry, sour cherry
Nuts	Almond, walnut, hazelnut, chestnut, pecan nut, pistachio nut, pine nut
Other fruits	Kiwi fruit, persimmon, fig, grape, strawberry, mulberry, fig, seabuckthorn, olive
Berries	Blackberries, raspberries, loganberry, blueberries, huckleberries, cranberries, currants, gooseberries,

fruits is substantial, with the Himalayan region being a significant contributor. Temperate fruit cultivation is a major source of income for farmers in the Himalayan states, particularly in remote and mountainous regions (Figure 1). These crops contribute significantly to the rural economy by generating employment opportunities, supporting agro-based industries, and enhancing household incomes. The export of certain temperate fruits, such as apples, contributes to foreign exchange earnings and trade balance. The productivity of temperate fruit crops varies across regions and depends on factors such as altitude, soil type, and orchard management practices. While some areas achieve high yields per hectare, there is still room for improvement through the adoption of modern cultivation techniques.

Current Area and Production Scenario of the Temperate Fruit Industry in India

The horticultural sector in India has emerged as a formidable force in global production, positioning the nation as the second-largest producer worldwide. In the year 2022-23, India's horticultural output soared to an estimated 351.92 million tons, marking a noteworthy increase of approximately 4.74 million tons (1.37%) compared to the preceding year. Fruit crops, a pivotal component of this sector on a global scale, occupy an expansive area of approximately 68.05 million hectares, yielding a staggering 867.77 million metric tons annually, averaging 12.75 tons per hectare. India's substantial contribution to this domain is evidenced by its fruit production, totaling around 107.51 million metric tons, cultivated across 7.06 million hectares, boasting an impressive average productivity of 15.22 tons per hectare. There are several dozens of temperate fruit crops from pome, stone, nuts, berries and other groups (Table 1). However, only 25 to 30 fruits/nuts are commercially grown around the world for fresh fruits as well as processed products (Retamales, 2011; Verma *et al.,* 2013).

Almond, apple, apricot, kiwi fruit, peach, pear, pecan, plum and walnuts are commercially cultivated in the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and Arunachal Pradesh (Mandal *et al*., 2021). In addition, a small area is increasing under low chills temperate fruits like apples, pears, peaches and plums in Punjab, Sikkim, Chhattisgarh, Nagaland, Tamil Nadu, Haryana, Madhya Pradesh, Mizoram, Manipur, West Bengal, Kerala, Maharashtra and Telangana (Table 2). As per the reports published by the Ministry of Agriculture and Farmers Welfare (PIB, 2022), the total temperate fruit production is 3417.91 thousand metric tons from an area of 520.92 thousand hectares. The average productivity is 6.56 t/ha and ranges from 1.20 t/ha (West Bengal) to 21.09 t/ha (Punjab). The maximum productivity among the different states was recorded in Punjab (21.09 t/ha) followed by Haryana (14.27 t/ha), Tamil Nadu (14.27 t/ha), Madhya Pradesh (11.54 t/ha), Manipur (10.45 t/ha), J&K (8.28 t/ha), Nagaland (6.99 t/ha), Himachal Pradesh (4.51 t/ha), Chhattisgarh (4.05 t/ha). The low productivity levels are mainly from high chilling areas (J&K, HP, UK and Arunachal Pradesh) as compared to low chill areas located in Punjab, Haryana and Tamil Nadu (Tables 2 & 3).

Among the temperate fruit crops, the maximum average productivity was recorded in apple (8.20 t/ha) followed by pear (7.05 t/ha), and peach (6.33 t/ha). However, the minimum productivity levels are generally recorded in nut crops, *viz.,* pecan nut (0.54 t/ha), almond (1.72 t/ha) and walnut (2.79 t/ha) (Table 3). The commodity-based largest producers' states are almond J&K for almond, apple and walnut; Arunachal Pradesh for kiwi fruit; Punjab for pear and peach; Himachal Pradesh for pecan nut and Uttarakhand for plums. The data regarding apricots is not available from the above source; however, Ladakh is the largest apricot-producing area in the country (Table 4). The maximum area is covered by apple (60.33%) followed by walnut (19.87%), pear (8.42%), plum (4.58%), peach (3.68%), almond (1.97%) and pecan nut (0.17%). Similarly in production, the largest volume is made up of apple (75.60%) followed by pear (9.04%), walnut (8.45%), peach (3.55%), plum (2.53%), almond (0.35%) and pecan nut (0.01%) (Table 3). The state-wise detailed data regarding area, production and productivity under different crops are given in Table 4. The range of productivity is varied widely among various crops

Table 2: Area, production and productivity of temperate fruits in India during 2021-22 (PIB, 2022)

	Major temperate fruit crops grown	*Area ('000 ha)*	*Production ('000 MT)*	*Productivity (t/ha)*
Jammu & Kashmir	Almond, apple, apricot, kiwifruit, peach, pear, plum and walnut	275.70	2281.81	8.28
Himachal Pradesh	Almond, apple, apricot, kiwi fruit, peach, pear, pecan, plum and walnut	145.64	657.08	4.51
Uttarakhand	Almond, apple, apricot, kiwi fruit, peach, pear, plum and walnut	74.35	245.12	3.30
Arunachal Pradesh	Apple, kiwi fruit, peach, pear, plum and walnut	9.12	15.13	1.66
Punjab	Peach, pear and plum	7.47	157.53	21.09
Sikkim	Kiwi fruit, peach, pear	2.21	6.64	3.00
Chhattisgarh	Pear	2.12	8.58	4.05
Nagaland	Apple, kiwi fruit, peach, pear, plum	1.44	10.07	6.99
Tamil Nadu	Peach, pear, plum	1.11	15.84	14.27
Haryana	Peach, pear, plum	0.68	11.17	16.43
Madhya Pradesh	Pear, plum	0.41	4.73	11.54
Mizoram	Kiwi fruit	0.30	1.03	3.43
Manipur	Kiwi fruit	0.29	3.03	10.45
West Bengal	Kiwi fruit	0.05	0.06	1.20
Kerala	Almond, peach	0.02	0.05	2.50
Maharashtra	Plum	0.01	0.03	3.00
Telangana	Apple	-	0.01	-
Total		520.92	3417.91	6.56

Table 3: Crop-wise area, production and productivity of major temperate fruit crops in India during 2021-22 (PIB, 2022)

Crops	*Area ('000 ha)*	*%share in total area*	*Production ('000 MT)*	*%share in total production*	*Productivity (t/ha)*
Almond	10.27	1.97	12.04	0.35	1.72
Apple	314.25	60.33	2584.01	75.60	8.2
Kiwi fruit	5.09	0.98	15.84	0.46	3.11
Peach	19.16	3.68	121.21	3.55	6.33
Pear	43.85	8.42	309.01	9.04	7.05
Pecan nut	0.91	0.17	0.49	0.01	0.54
Plum	23.86	4.58	86.4	2.53	3.62
Walnut	103.5	19.87	288.79	8.45	2.79
Total	520.89	100.00	3417.79	100.00	

(Table 5). In addition, information is given on share under area and production with productivity levels for respective crops under different states in Table 6.

The above data are clear indicative that the yield level is very low among all the temperate fruit crops in entire temperate regions of the country. However, the low-chilling temperate fruit crops, mainly pear, peach and plum, are doing well in the sub-tropical areas of Punjab, Haryana and Tamil Nadu. Therefore, there is an urgent need to increase the productivity levels in the temperate regions of the country. In addition, area expansion under sub-tropical areas is profitable to harness the potential of temperate fruit crops utilizing low chill varieties.

Import-Export Scenario of the Temperate Fruit Crops in India

Production, marketing and trade are an integral part of the fruit crop industry (Atteri, 2003). As per the reports published by FAO (2022), India is importing 31 commodities related to temperate fruit and nut crops as fresh fruits as well as value-added products to the tune of 855,534.07 thousand metric tons and spending 1,999,360 thousand USD. However, exporting the small quantity (56,266.38 thousand metric tons) of temperate fruits including value added products and earning foreign exchange of 33,584 thousand USD (Table 7). That resulted in the huge negative balance of trade (BoT) to the tune of 1,965,776 USD during year 2022.

Table 4: Temperate fruit growing states in India (2021-22)

Crop	Area, production and productivity in major states
Almond	Jammu and Kashmir (5,460 ha; 9,810 MT; 1.80 t/ha), H.P. (4,800 ha; 2,220 MT; 0.46 t/ha), Kerala (10 ha)
Apple	Jammu and Kashmir (168,570 ha; 1,898,590 MT, 11.26 t/ha), HP (1,150,20 ha; 611,900 MT, 5.32 t/ha), Uttarakhand (25,980 ha; 64,880 MT; 2.50 t/ha), Arunachal Pradesh (4,440 ha; 6,830 MT; 1.54 t/ha), Nagaland (240 ha; 1,780 MT; 7.41 t/ha), Kerala (10 MT); Tamil Nadu (10 MT), Telangana (10 MT).
Kiwi fruit	Arunachal Pradesh (3,560 ha, 7,110 MT; 2.00 t/ha), Manipur (290 ha; 3,030 MT; 10.45 t/ha), Sikkim (410 ha; 2,170 MT; 5.29 t/ha), Nagaland (300 ha; 1,690 MT; 5.63 t/ha), Mizoram (300 ha; 1,030 MT; 3.43 t/ha), Himachal Pradesh (200 ha; 720 MT; 3.70 t/ha), Jammu and Kashmir (300 MT), West Bengal (50 ha; 60 MT; 1.20 t/ha).
Peach	Punjab (2,620 ha; 46,980 MT; 17.93 t/ha), Uttarakhand (8,280 ha, 52,860 MT; 6.38 t/ha), Tamil Nadu (660 ha; 9,910 MT; 15.01 t/ha), Jammu and Kashmir (2,500 ha; 7,600 MT; 3.02 t/ha), Himachal Pradesh (4,900 ha; 5,800 MT, 1.18 t/ha), Haryana (330 ha; 5,380 MT; 16.80 t/ha), Nagaland (260 ha; 1,770 MT; 6.81 t/ha), Tamil Nadu (70 ha; 400 MT; 5.71 t/ha), Sikkim (140 ha; 330 MT; 2.56 t/ha), Arunachal Pradesh (50 ha; 70 MT; 1.40 t/ha), Kerala (10 ha; 30 MT; 3.00 t/ha).
Pear	Punjab (4,340 ha; 101,570 MT; 23.40 t/ha), Jammu and Kashmir (14,160 ha; 81,530 MT; 12.26 t/ha), Uttarakhand (13,250 ha, 73,780 MT; 5.57 t/ha), Himachal Pradesh (6,650 ha; 19,520 MT, 2.94 t/ha), Chhattisgarh (2,120 ha; 8,580 MT; 4.05 t/ha), Haryana (270 ha; 4,540 MT; 16.81 t/ha), Sikkim (1,660 ha; 4,140 MT; 2.49 t/ha), Madhya Pradesh (250 ha; 2,820 MT; 11.28 t/ha), Nagaland (200 ha; 2,060 MT; 10.30 t/ha), Arunachal Pradesh (290 ha; 560 MT; 1.93 t/ha), Kerala (10 MT).
Pecan nut	Himachal Pradesh (910 ha; 490 MT; 0.54 t/ha)
Plum	Uttarakhand (9,080 ha, 34,840 MT; 3.84 t/ha), Jammu and Kashmir (4,280 ha; 16,820 MT; 3.93 t/ha),Himachal Pradesh (8,900 ha; 14,160 MT; 1.59 t/ha), Punjab (510 ha; 8,980 MT; 17.61 t/ha), Tamil Nadu (380 ha; 5,520 MT; 14.53 t/ha), Nagaland (440 ha; 2,770 MT; 6.30 t/ha), Madhya Pradesh (160 ha; 1,910 MT; 11.94 t/ha), Haryana (80 ha; 1,250 MT; 15.63 t/ha), Arunachal Pradesh (40 ha; 140 MT; 3.50 t/ha), Maharashtra (10 ha; 30 MT; 3.00 t/ha).
Walnut	Jammu and Kashmir (80,730 ha; 267,160 MT; 3.31 t/ha), Uttarakhand (17,760 ha, 18,760 MT; 1.07 t/ha), Himachal Pradesh (4,260 ha; 2,270 MT, 0.53 t/ha), Arunachal Pradesh (740 ha; 420 MT; 0.57 t/ha).

Table 5: Productivity scenario of the different fruit crops in India

Crop	*Range (t/ha)*	*Average (t/ha)*	*Maximum (t/ha)*
Almond	0.46 (HP)-1.80 (J&K)	1.13	1.86 (J&K)
Apple	1.54 (Arunachal Pr.) – 11.26 (J&K)	8.22	11.26 (J&K)
Kiwi fruit	1.20 (West Bengal) – 10.45 (Manipur)	3.15	10.45 (Manipur)
Peach	1.18 (HP) – 17.93 (Punjab)	6.33	17.93 (Punjab)
Pear	1.93 (Arunachal Pr.)-23.40 (Punjab)	7.05	23.40 (Punjab)
Pecan nut	0.54 (HP)	0.54	0.54 (HP)
Plum	1.59 (HP) -17.61 (Punjab)	3.62	17.61 (Punjab)
Walnut	0.53 (HP) – 3.31 (J&K)	2.79	3.31 (J&K)

Only seven commodities made a largest volume of imports (97.91%), which includes apple (47.05%) followed by almonds (28.12%), olives (7.24%), kiwi fruit (5.37%), walnut (3.86%), pears (3.72%) and pistachio nut (2.55%). In terms of value, 96.48% of the foreign exchequer spent towards the imports of only 5 commodities which includes almonds (51.00%) followed by apples (16.28%), olives (14.57%), pistachio nuts (8.45%), kiwi fruits (3.15%) and walnuts (3.03%). However, the maximum exported commodities in terms of value are only three commodities which include apple (94.20%) followed by walnut (2.42%) and almond (1.40%) accounting for a total of 98.02% imports (Table 7 & Figure 2).

During 2022, the growth rate in import and export commodities were assessed based on the previous year data (2021). In earlier years the import quantities were significantly very high, but in the representative year, imports have been slightly reduced in the commodities which are causing loss of foreign exchequer. As a result, there is a marginal decrease in imports and a slight increase in exports has been recorded (Table 8). The maximum imported commodities include almonds, apples, walnuts, kiwi fruit, olive and pistachio nuts. Except for olives, the rest of the commodities were reduced in term of volume as well as value. This a step towards the *Atmnirbhar Bharat*. However, the demand for olives is still on the higher side, particularly olive oil which has increased many folds in the year 2022. In rest of the commodities, the growth was found insignificant in terms of quantity and value. The export of apples has taken new dimensions, which has increased for fresh fruits as well as apple juice. Apple is the only potential commodity that can be exploited on large scale through quality fruit production, strengthening of the infrastructure and streamlining of the market linkage and collaboration. Kiwi fruits, peaches and apricots are also having a bright future for meeting the domestic demand as

Table 6: State-wise area, production, productivity and percentage share under different temperate fruits in India during 2021-22 (PIB, 2022). Values in brackets are indicated as percentage shares.

Crop	*Parameters*	*JK*	*HP*	*Kerala*	*Nag-aland*	*Tamil Nadu*	*Telen-gana*	*UK*	*Aruna-chal Pradesh*	*Mani-pur*	*Mizo-ram*	*Sikkim*	*w Bengal*	*Haryana*	*Punjab*	*CHG*	*MP*	*Maha-rashtra*	*Total*
Almond	Area ('000 ha)	5.46 (53.16%)	4.80 (46.74%)	0.01															10.27
	Production ('000 MT)	9.81 (81.55%)	2.22 (18.45%)																12.03
	Productivity (t/ha)	1.80	0.46	0															1.13
Apple	Area ('000 ha)	168.570 (53.64%)	115.02 (36.60%)	0	0.24			25.98 (8.27%)	4.44 (1.41%)										314.25
	Production ('000 MT)	1898.59 (73.47%)	611.90 (23.68%)	10	1.78	10	10	64.88 (2.67%)	6.83										2584.01
	Productivity (t/ha)	11.26	5.32		7.42			2.50	1.54										8.22
Kiwi fruit	Area ('000 ha)		0.20 (3.91%)		0.30 (5.87%)				3.56 (69.67%)	0.29 (5.68%)	0.30 (5.87%)	0.41 (8.02%)	0.05 (0.98%)						5.11
	Production ('000 MT)	0.30 (1.86)	0.72 (4.47%)		1.69 (10.49%)				7.11 (44.13%)	3.03 (18.81%)	1.03 (6.39%)	2.17 (13.47%)	0.06						16.11
	Productivity (t/ha)		3.60		5.63				2.00	10.45	3.43	5.29	1.20						3.15
Peach	Area ('000 ha)	2.50 (13.05%)	4.90 (25.57%)	0.01	0.26 (1.61%)	0.07		8.28 (43.22%)	0.05			0.14 (0.73%)		0.33 (1.72%)	2.62 (13.67%)				19.16
	Production ('000 MT)	7.60 (6.27%)	5.80 (4.78%)	0.03	1.77 (1.46%)	0.40		52.86 (43.61%)	0.07			0.33		5.38 (4.44%)	46.98 (38.76%)				121.22
	Productivity (t/ha)	3.04	1.18	3.00	6.81	5.71		6.38	1.40			2.36		16.30	17.93				6.33
Pear	Area ('000 ha)	14.16 (32.29%)	6.65 (14.50%)		0.20 (0.46%)	0.66 (1.44%)		13.25 (30.22%)	0.29 (0.66%)			1.66 (3.79%)		0.27 (0.62%)	4.34 (9.90%)	2.12 (4.83%)	0.25 (0.57%)		43.85
	Production ('000 MT)	81.53 (26.38%)	19.52 (6.32%)	0.01	2.06 (0.67%)	9.91 (3.21%)		73.78 (23.88%)	0.56 (0.18%)			4.14 (1.34%)		4.54 (1.47%)	101.57 (32.87%)	8.58 (2.78%)	2.82 (0.91%)		309.02
	Productivity (t/ha)	5.76	2.94		10.30	15.02		5.57	1.93			2.49		16.81	23.40	4.05	11.28		7.05

Pecan	Area ('000 ha)		0.91 (100%)									0.91
	Production ('000 MT)		0.49 (100%)									0.49
	Productivity (t/ha)		0.54									0.54
Plum	Area ('000 ha)	4.28 (17.92%)	8.90 (37.27%)	0.44 (1.84%)	0.38 (1.59%)	9.08 (38.02%)	0.04	0.08	0.51 (2.14%)	0.16 (0.67%)	0.01	23.88
	Production ('000 MT)	16.82 (19.46%)	14.16 (16.39%)	2.77 (3.21%)	5.52 (6.39%)	34.84 (40.31%)	0.14 (0.16%)	1.25 (1.45%)	8.98 (10.39%)	1.91 (2.21%)	0.03	86.42
	Productivity (t/ha)	3.93	1.59	6.30	14.53	3.84	3.50	15.63	17.61	11.94	3.00	3.62
Walnut	Area ('000 ha)	80.73 (78.01%)	4.26 (4.12%)			17.76 (17.16%)	0.74 (0.72%)					103.49
	Production ('000 MT)	267.16 (92.57%)	2.27 (0.79%)			18.76 (6.50%)	0.42 (0.15%)					288.61
	Productivity (t/ha)	3.31	0.53			1.06	0.57					2.79

well as export to other countries through proper planning and management from farm level to market intelligence.

Plant Genetic Resources of Temperate Fruits

Temperate fruit crops including pome fruits (apple, pear & quince), stone fruits (peach, plum, nectarine, apricot & cherry), nut crops (walnut, almond, hazelnut, pecan & pistachio), minor fruits (olive, kiwi fruit, persimmon, berries etc) are being maintained at NAGs. Backup of germplasm is being taken up at ICAR-NBPGR, New Delhi in the form of dormant buds through cryopreservation. About 200 accessions of apple are being maintained in the field genebank of each ICAR Institutes, *viz.*, ICAR-NBPGR Regional Station, Shimla (241 acc.); YSPUHF Regional Horticultural Research and Training Station, Mashobra (238 acc.); ICAR-CITH, Srinagar (~200 acc.; 7 species); IARI, Shimla; GBPUAT, Pantnagar; SKUAST, Srinagar. Thirty accessions of Malus varieties, including Red Delicious and rootstocks, are being conserved as *in vitro* cultures at National Genebank, ICAR-NBPGR, New Delhi. Dormant bud cryopreservation has been emphasized to have a cost-effective back up of the germplasm growing in the field gene banks. A large collection of pears is being maintained in the field gene banks of ICAR-CITH, Srinagar (35) NBPGR Regional Station, Shimla (87); YSPUHF Regional Horticultural Research and Training Station, Mashobra (63); SKUAST, Srinagar and GBPUAT, Pantnagar. In addition, 73 accessions of exotic pears procured from USA are being conserved *in-vitro* at National Genebank, ICAR-NBPGR. In addition to apple and pear, these Institutions also maintain and conserve germplasm of other crops like peach, plum, cherry, apricot etc. Germplasm of walnut and almond is mainly being maintained and conserved at ICAR-CITH, Srinagar. More than 20 accessions of *Rubus* spp. are being maintained in the filed gene banks of ICAR NBPGR Regional Station Shimla and Bhowali. In addition, 62 exotic accessions of blackberry and 21 accessions of blueberry procured from National Clonal Germplasm Repository, Corvallis, USA are being maintained *in vitro* at National Genebank, ICAR-NBPGR, New Delhi (Dar *et al.*, 2018; Dhillon and Rana, 2003; Hassan *et al.,* 2018; Madhu *et al.,* 2023).

Germplasm Introduction and Exchange

Introduced crops are either directly used as varieties (primary introduction) or used in breeding for improving quality, productivity and imparting resistance (Secondary introduction). The NBPGR has been instrumental in introducing many new varieties like 'Red Delicious' apple, 'Bartlett' pear, 'Elberta' peach, 'Santa Rosa' plum, & 'Thompson Seedless' grapes, etc. (Singh, 2010). In apple, introduction of varieties and rootstocks is the continuous process because new varieties are being developed with better quality leading to their higher demands and acceptability. In 2009, varieties like 'Golden Delicious

Table 7: Import and export of horticultural commodities during 2022 (FAOSTAT, 2022)

Commodity	*Import*				*Export*			
	Quantity ('000 MT)	*% Share*	*Value (1000 USD)*	*% Share*	*Quantity (MT)*	*% Share*	*Value (1000 USD)*	*% Share*
Almond in shell	233746	27.322	967648	48.398	316.64	0.563	1610	0.563
Almond shelled	6810.45	0.796	52096	2.606	473.12	0.841	3023	0.841
Almond (Total)	240556.4	28.118	1019744	51.004	789.76	1.404	4633	1.404
Apple juice	38.46	0.004	35	0.002	2.51	0.004	1	0.004
Apple juice conc	10006.46	1.170	11180	0.559	106.45	0.189	215	0.189
Apples	392482.9	45.876	314345	15.722	52892.13	94.003	21346	94.003
Apple (total)	402527.8	47.050	325560	16.283	53001.09	94.197	21562	94.197
Apricot	759.41	0.089	1560	0.078	1.86	0.003	3	0.003
Apricot dried	5649.19	0.660	17066	0.854	71.42	0.127	331	0.127
Apricot (Total)	6408.6	0.749	18626	0.932	73.28	0.130	334	0.130
Cherries	1462	0.171	9148	0.458	12.18	0.022	6	0.022
Chestnut	0.31	0.000	1	0.000	14.77	0.026	52	0.026
Cranberries	860.3	0.101	5331	0.267	4.56	0.008	6	0.008
Currants	117.68	0.014	106	0.005	256.53	0.456	207	0.456
Hazelnut in shell	0.14	0.000	2	0.000	1.01	0.002	8	0.002
Hazelnut shelled	328.08	0.038	2382	0.119	9.15	0.032	66	0.016
Hazelnut (Total)	328.22	0.038	2384	0.119	10.16	0.018	74	0.018
Kiwi fruit	45935.79	5.369	63051	3.154	134	0.238	169	0.238
Olive pomace oil	3111.99	0.364	7435	0.372	2.05	0.004	6	0.004
Olive oil	53784.07	6.287	275629	13.786	40.26	0.072	214	0.072
Olives	0.08	0.000	1	0.000	0.49	0.001	0	0.001
Olive preserved	5079.63	0.594	8179	0.409	37.88	0.067	100	0.067
Olive (Total)	61975.77	7.244	291244	14.567	80.68	0.143	320	0.143
Peach nectarine	259.46	0.030	421	0.001	2.28	0.004	12	0.004
Pears	31834.34	3.721	32518	1.626	152.11	0.270	295	0.270
Persimmon	38.33	0.004	104	0.005	44.38	0.079	18	0.079
Pistachio in shell	21842.24	2.553	168903	8.448	28.17	0.050	249	0.052
Plums	6210.03	0.726	6008	0.300	201.32	0.358	68	0.358
Plum dried	2124.39	0.248	4878	0.244	15.93	0.028	79	0.028
Plum (Total)	8334.42	0.974	10886	0.544	217.25	0.386	147	0.386
Quince	0.01	0.000	0	0.000	0.2	0.059	0	0.000
Raspberries	9.72	0.001	75	0.004	72.36	0.129	207	0.129
Sour cherry	1.9	0.000	16	0.001	0.23	0.000	0	0.000
Strawberry	37.92	0.004	335	0.017	10.02	0.018	14	0.018
Walnut in shell	30798.25	3.600	50907	2.546	383	0.681	883	0.681
Walnut shelled	2204.59	0.258	9694	0.485	979.37	1.741	4396	1.741
Walnut (total)	33002.84	3.858	60601	3.031	1362.37	2.421	5279	2.421
Total	855534.07		1999360.00		56266.38		33584.00	

Reinders', 'Granny Smith', 'Gale Gala', 'Red Chief,' 'Camspur Spur' *etc* were introduced. In 2013, 'Super Chief Sandidge', 'Fuji Aztec', 'Gala Red Lum', 'Golden-Clone B', and 'Red Velox' were introduced and now more emphasis is given on introduction of new colored strains of 'Gala' like 'Gala Schinico Red', 'Gala T-Rex', 'Gala Dark Baron', 'Gala Nerissimo' etc and colour strains of 'Delicious' group like 'King Roat', 'Scarlet Spur-II', 'Jeromine', 'Zad-1', 'Adams' etc. Introduction

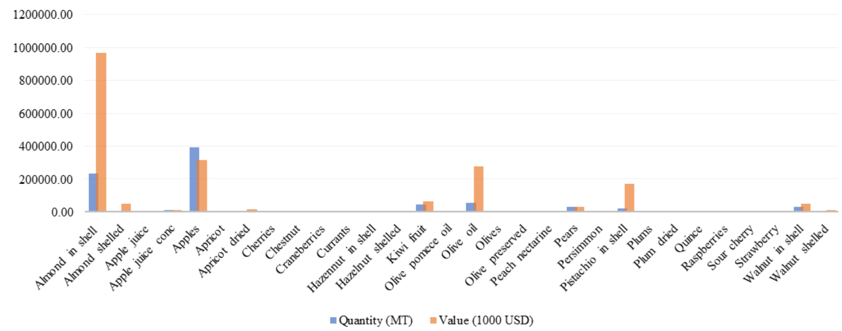

Figure 2: Imports of the temperate fruits and nut crops including value added products in India during 2022

Table 8: Growth in import and export of the temperate fruit commodities during (FAO, 2022)

Commodity	*Imports*		*Exports*	
	Quantity (%)	*Value (%)*	*Quantity (%)*	*Value (%)*
Almond in shell	6.06	12.00	-19.50	-15.26
Almond shelled	-57.80	-54.46	165.32	153.18
Apple juice	-75.30	-64.28	1294.44	-
Apple juice conc	-43.94	-40.56	-37.67	-44.87
Apples	-10.02	-16.71	82.07	48.80
Apricot	61.03	116.06	33.81	-25.0
Apricot dried	26.33	33.25	69.20	80.87
Cherries	122.42	98.09	461.12	100
Chestnut	34.78	-75.0	-36.0	-30.0
Cranberries	149.14	196.99	19.06	-14.28
Currants	488.4	100	-33.99	-40.85
Hazelnut in shell	-96.5	-89.47	910.0	-
Hazelnut shelled	25.86	14.68	9.15	34.69
Kiwi fruit	-31.70	-8.70	14.71	14.96
Olive pomace oil	-34.20	-8.37	540.63	100
Olive oil	531.99	575.51	-0.40	6.46
Olives	-52.94	-50.0	22.5	-
Olive preserved	39.18	32.18	1219.86	1150
Peach nectarine	-22.02	24.92	1100	1100
Pears	27.88	21.89	57.94	69.54
Persimmon	-1.72	4.0	28.64	63.64
Pistachio in shell	-20.65	-18.64	-48.29	-47.57
Plums	35.27	44.42	-24.27	-20.0
Plum dried	77.66	284.70	-89.58	-27.52
Raspberries	68.75	29.31	24.76	11.29
Sour cherry	-97.34	-97.25	-	-
Strawberry	74.26	87.15	-56.75	-65.85
Walnut in shell	-18.87	-31.02	-45.50	-43.17
Walnut shelled	-22.48	-23.47	-30.73	-36.44

of new strains of 'M-9' rootstock like 'M9-T337', 'M9-T339', 'M9-Pajam-1' etc has been initiated since 2013 and are being introduced on large scale. In cherry, self-fruitful varieties ('Lapins', 'Stella' *etc*) and clonal rootstocks are being imported by development departments, SAUs and other research Institutions. In almond more emphasis will be given on import of self-fruitful ('Independence', 'Shasta', 'Tuono' *etc*) & late blooming varieties ('Tardy Nonpareil', 'Ferralise', 'Ferragnese' *etc*) for commercialization and breeding programmes. In walnut, lateral bearing varieties ('Chandler', 'Fernor' etc) with respective pollinizer combinations ('Franquette', 'Fernette' *etc*) are being introduced on large scale for replacement of existing non-descriptive varieties to enhance yield and quality. Introduction of new varieties on large scale need quality testing to rule out the possibility of introduction of any pest or disease, therefore PEQ facilities at Srinagar (J &K); Mukteshwar (Uttarakhand) and Dirang (Arunachal Pradesh) have been established by ICAR under ICAR-Central Institute of Temperate Horticulture, Srinagar as Nodal Agency.

Breeding for Introgression and Development of Desirable in Commercial Varieties

Programmes for improvement in crops like apple, pear, almond and walnut have already been initiated by ICAR-CITH, Srinagar in 2009. Hybridization programme in apple for introgression of scab resistance in commercial apple cultivars and indigenous apple cultivar 'Ambri' has led to development of four hybrids ('Pride', 'Priame', 'Ammol' & 'Golden Snow') with desirable traits. 'Pride' ('Prima' x 'Red Delicious') and 'Priame' ('Prima' x 'Ambri') are scab resistant hybrids with better fruit quality traits than any existing scab resistant variety available in the world (Mir *et al.,* 2017; 2020). 'Ammo'l ('Ambri' x 'Mollies Delicious') is the coloured early maturing 'Ambri' derivative with excellent fruit quality traits like aroma, colour and extended shelf life. 'Golden Snow' ('Golden Delicious' x 'Snow Drift') is hybrid with pollinizer ability possessing excellent fruit quality traits like high TSS, lusture, creamy colour, resistance to russeting etc. Similarly breeding in pear for developing good quality, low chill and disease resistant varieties have been initiated in 2018. In walnut, hybridization programme

Table 9: Target traits and sources for breeding programmes in temperate fruits and nuts

Crop	*Trait*	*Gene*	*Source*	*Breeding strategy*
Apple	Scab resistance	Vf (Rvi6)	Prima, *M. floribunda*	MAB/ Cisgenics
	Fire blight resistance	Dm-1	*M. floribunda*	Cisgenics
	Alternaria resistance	Alt-1	*M. seiversii*	Cisgenics
	Precocity	TFL	Not known	Genome editing
	Columnar nature	Co	Wijcik	MAB
	Wooly apple aphid resistance	Er	Northern Spy	Cisgenics
	Rosy apple aphid resistance	Smh	*M. robusta*	Cisgenics
	Rosy curling aphid resistance	Sd	*Malus robusta*, 'McIntosh	Cisgenics/MAB
Pear	Scab resistance	Rvn/Rvi1	*Pyrus ussuriensis*, Bartlett (Williams), Beurre Hardy	MAB
	Pear psylla resistance	Py/Rvp1	Karamanka, Jerisbasma, Vodenjac	Hybridization /MAB
Walnut	Lateral bearing	L	Chandler, Fernor	Hybridization/MAB
	Precocity	Jrhd1	Not known	MAB
Almond	Self-fruitfulness	Sf	Independence, Shasta, Tuono	Hybridization/MAB
	Late blooming	Lb	Tardy Nonpareil, Ferragnese, Ferralise	Hybridization/MAB
	Sweet kernel	Ma/Sk	Prunus fenzliana	Cisgenics
Cherry	Self-fruitfulness	Sf	Stella, Sweetheart, Lapins	Hybridization/MAB
Apricot	Sweet kernel	Ma/Sk	*Prunus brigantina*	Cisgenics

of introgression of lateral bearing and nut quality traits has been taken up by different institutions including ICAR-CITH, Srinagar, SKUAST-K, Srinagar etc. For almond improvement hybridization programmes for traits like self-fruitfulness and late blooming are going on (Table 9).

Nutritional Strength of Temperate Fruits for Nutritional Security

Indian Himalayan region is rich in diversity in *Rubus*, *Ribes*, *Docynia*, *Cydonia*, *Myrica* and *Elaegnus* minor temperate fruits. These fruit crops are brought to Himalayan region for thousands of years not only survived but got established in the hills, leading to evaluation of new varieties. These species have been naturalized and some important selection can be evolved from few of them for exploitation. These fruit crops have already been in use by hill peoples and significantly contributed to the economy of tribal farmers. These fruit crops are excellent source of various nutrients, vitamins and antioxidants. The *Rubus* and *Ribes* are already been exploited in the developed countries and rated on top ten fruits available at global level based on maximum antioxidants. Initiatives for their collection, introduction and popularization is required to harness their immense nutritional potential for nutritional security of the country in future (Table 10).

Berries like blueberry, black berry and strawberries are well known for their high flavonol and anthocyanin contents, as well as elevated antioxidant activities by the oxygen radical absorbance capacity assay. Pears contain catechin (flavanol), caffeic, chlorogenic, and gallic acid (phenolic acids), as well as arbutin (glucoside) which are highly beneficial for human health. Apples are reportedly high in polyphenolic antioxidants, although these are reportedly high in the peels in comparison to the pulp. An apple a day keeps doctor away is used to dictate the nutraceutical properties of apple. Phenolic antioxidant activities have been shown to chelate and stabilize divalent cations, inhibit lipoxygenase, and scavenge free radicals (Ozcan *et al*. 2014). Furthermore, flavonoids, phenolic acids, and tannins have been shown to be anticarcinogenic and antimutagenic. Noroozi *et al*. (1998) reported the synergistic protective effects of l-ascorbic acid and flavonoids against oxidative DNA damage of lymphocytes. However, the absorption and bioavailability of some phytochemicals, such as anthocyanins, is reportedly low, while their metabolism is not implicit (Wu *et al*. 2002). Furthermore, the antioxidant capacity of some fruit extracts, such as strawberries, has been shown to be positively related to their antiproliferative activities. Like phenolic compounds, carotenoids are plant secondary metabolites with numerous functions in both plant and human physiology. In temperate fruits the concentrations as well as the interactions of carotenoids and chlorophyll are known to be responsible for the red, orange, and yellow coloration. Although apples are generally known to be low in carotenoids, it has been shown that carotenoids are high at the onset of development in the fruits but are lost as they mature.

Use of Crop Wild Relatives

The cultivated apple, *Malus domestica* Borkh., is a diploid or triploid species with a haploid set of 17 chromosomes and a genome size of approximately 600 Mb. Apple cultivation

Table 10: Temperate fruits are rich source of nutraceutical compounds

Nutraceutical factors	*Nutraceutical rich fruit crops*
Flavonoids (Anthocyanidins): Cyanidin 3-glycosides, Malvidin, Delphinidin, Pelargonidin	Blue berries, black berries, cranberry, raspberry, black currant, black grape, strawberries, cherries, plums, pomegranate
Flavanols: Morin, Procyanidins Prodelphinidins, Catechin, Epicatechin and their gallates	Apricots, apples, grapes, peaches, pears, plums, berries, cherries
Anthoxanthins (Flavonols): Myricetin, Fisetin, Quercetin, Kaempferol, Isorhamnetin	Cherry, apples, apricots, grapes, plums, berries, currants, cherries,
Phenolic acids: Chlorogenic acid, Ferulic acid, p-coumaric acid Ellagic acid, Gallic acid	Peach, cider, Strawberry, raspberry, grape, pomegranate, blueberry, cranberry, pear, cherry, apple
Tannins: Catechin, Epicatechin polymers, Ellagitannins, Proanthocyanidins, Tannic acids	Pomegranate, walnuts, peach, olive, plum, grape seeds apple, strawberries, raspberries, blackberry,

and production constitute one of the major fruit-producing industries addressing markets worldwide. However, climatic changes introduce a series of environmental stressors which challenge apple yield and fruit quality. Apple breeding could greatly benefit from apple wild relatives to face the challenge from adverse environmental conditions and biotic and abiotic stressors. For example, wild relatives, *Malus floribunda*, *Malus baccata,* and *Malus micromalus,* have been used to pyramid apple scab and powdery mildew resistance genes into progeny. Assessment of a broad range of wild Malus germplasm over the last 30 years has revealed ample potential sources of resistance to a multitude of diseases. Similarly, apple wild relatives in Malus collections have been evaluated and shown to possess traits related to fruit quality as well as abiotic stress resilience, such as cold hardiness and drought tolerance. In addition, investigations on the molecular basis of stress tolerance have indicated a key role for a DREB2 (dehydration-responsive element-binding factor 2) homologue in response to drought, cold, and heat in two highly drought-tolerant wild apple relatives, *Malus sieversii* and *M. prunifolia*. Likewise, *Diacylglycerol kinase* (*DGK*) genes were found to exhibit marked upregulation in response to drought and salt stress in *M. prunifolia*. Moreover, the deciphering of the cold-tolerant wild apple *Malus baccata* genome identified cold-responsive genes (*COR*) that will be useful in marker-assisted selection in breeding programs. Collectively, the wild relatives of any temperate crop like apple, pear, cherry etc provide an important genetic resource for incorporating resilience in cultivated varieties (Mir *et al.,* 2017b; Rana *et al.,* 2007; Verma *et al.,* 2023).

Varietal Wealth with Improved Fruit Quality and Higher Productivity

In true sense the temperate fruit crops have been commercially exploited in Europe, America and Australia where the work on improvement is in very advanced stage and were able to evolve several high yielding varieties having better quality and resistance to biotic and abiotic stresses. The new superior introductions from advance countries are now slowly replacing old varieties resulting in drastic changes in the production scenario of temperate fruit production (Kumar *et al.,* 2013; Lal *et al*., 2022; Sharma *et al*., 2004; Verma et al., 2013). The details of old varieties and new improved types grown in different states are given in Tables 11 and 12. In apple, during the last 50 years more than three hundred genotypes of apple have been introduced in India from Australia, Canada, Denmark, Germany, Israel, Italy, Netherlands, Russia, Switzerland, USA, and U.K., and have been tried and tested. Among various types the delicious group of cultivars predominates the apple market. The important varieties of apple in different types/groups are enumerated below.

Superior varieties

Oregon Spur, Rich a Red, Starkrimson, Red Chief, Well Spur, Hardeman, Gala Selection, Spartan, Gloster, Stark Spur, Top Red, Vance Delicious, Gold Spur, Silver Spur, Lal Ambri,

Color mutants

Vance Delicious, Top Red, Skyline Supreme.

Low chilling cultivars

Tropical Beauty, Mayaan, Michal, Schlomit, Chaubattia Princess and Chaubattia Anupam.

Early cultivars

Benoni, Irish Peach, Early Shanburry, Fanny

Juice making cultivars

Lord Lambourne, Granny Smith, Ellington Pippin.

Scab resistant cultivars

Priscilla, Sir Prize, Mac Free, Freedom, Coop-12, Coop-13, Firdaus, and Shireen.

Table 11: Promising cultivars of pome, stone and nut fruits identified for commercial cultivation in different states

Fruits	*J & K*	*H.P.*	*Uttarakhand*
Apple	Oregon Spur, Rich a Red, Starkrimson, Red Chief, Well Spur, Hardeman, Gala Selection, Spartan, Gloster, Stark Spur, Top Red, Vance Delicious, Gold Spur, Silver Spur, Lal Ambri, Skyline Supreme, Red Delicious, royal Delicious, mollies Delicious	Oregon Spur, Rich a Red, Starkrimson, Red Chief, Well Spur, Hardeman, Top Red, Vance Delicious, Gold Spur, Silver Spur, Vance Delicious, Royal Delicious, Tydeman's Early, Mollies Delicious, Red delicious, Golden Spur, Michal	Oregon Spur, Rich a Red, Starkrimson, Red Chief, Well Spur, Early Shan burry, Chaubattia Princess, Fanny, Benoni, Red Delicious, Starking Delicious, Rymer, Buckingham, Mollies Delicious
Pear	Max Red Bartlett, William, Red Bartlett, Starking, Early China, Laxton's Superb, Bartlett, Flemish Beauty, Conference, Kashmiri Nakh, Doyenne-du-Comice, Anjou, Fertility, Vicar of Wakefield.	China, Bartlett, Max Red Bartlett, Flemish Beauty, Manning's Elizabeth, Winter Nellis	Thumb Pear, Doyenne du Comice, Victoria, William's Bartlett, Beurre Hardy, Flemish Beauty
Apricot	New Castle, Kaisha, Early Shipley, Suffaida, Charmagaz, Shakarpara, Frogmore Early, Gillgati Sweet, Amba, Moorpark, Nari, Halman, Rakchey Karpo Narmo, Afgani, Tokpopa, Koban	Kaisha, Nugget, Castle, Saffaida, Charmagaz	Charmagaz Kaisha, Moorpark, Turkey, St. Ambrose
Plum	Methley, Kelsey, Red Beauty, Santa Rosa, Sweet Early, Satsuma, Burbank, Frontier, Mariposa, Duerret, Grand Duke, Stanley, Tilton	Kelsey, Santa Rosa, Titron, Satsuma, Mariposa	Jamuni, Kelsey, Santa Rosa, Titron
Peach	Red Haven, Star Red Gold, July Elberta, Sun Haven, JH Hale, Quetta, Florida Sun, Florida Red, Snow Queen (Nectarine), Cresthaven (Nectarine), Red June, Crawford Early, Alexander	Alton, July Elberta, JH Hale, Sharbati, Shan-e-Punjab, Burbank	Sharbati Saffaida, Flordasun, Shan-e-Punjab, Paradelux, Crawfold Early, July Elberta
Sweet Cherry	Bigarreau Noir Grosse (Misri), Guigne Pourpeara Pecoce (Awal), Bigarreau Napoleon (double) Black Heart, Guigne Pourpeara Prece, Guigne Noir Gross, Guigne Noir Hative, Bigarreau Napoleon, Bigarreau Noir Grosse, Stella, Compact Stella, Van and Bing	Black Tartarian, Napoleon, Sue Sam, Lambert, Bing	Bedford Prolific, Black Heart, Governor's Wood

Table 12: Shift in the varietal profile from traditional to modern planting systems

Crop	1st generation varieties (1900 to 1990)	2nd generation varieties (1990 to 2020)	3rd Generation Varieties (2020 onwards) (Fig. 3)
Apple	Red Delicious, Golden Delicious Jonathan, King of Pippin, Yellow Newton, Irish Peach, American Mother, Queens Apple, Rome Beauty, Scarlet Siberian Karry Pippin, Chumure, Baldwin, White Doted Red. Benoni, Razakwari	Starkrimson, Mollies Delicious, Oregon Spur, Red Chief, Top Red, Vance Delicious, Silver Spur, Rich a Red, Super More Gold. Lal Ambri, Red Gold, Sunheri, Cooper IV	Jeromine, King Roat, Gala Scarlet, Red Velox, Scarlet Spur-II, Super Chief, Redlum Gala, and Auvi Fuji, Mema Mester, Schinco Red Gala, Devil Gala, Burge Red, Bingo Gala, Cosmic Crisp, Red Delicious Fenzad, Gala Star, Gala Fenzam, Gala Fenplus, Gala T Rex
Pear	Doyne Bosc, Gent, Drauard, Fertility, Beureu Hardy, China Pear	Bartlett, Chinese Sandy Pear (Kashmiri Nakh), Vicar of Wing Field, Conference	Eden, Forelle, Vermont, Conference, Dor Eden
Cherry	Mishri, Double, Makhmali, Awal, Tontal	Van, Stella, Bing, Reinear, Compact Stella, Lapins, Sweet heart, Regina, Bing	Kordia, Regina, Aeko, Adana, Maxima, Sweetheart, Bing Stucato, Sonata, Samba, Royal Helen, Sofia, Rocket, Royal Tioga
Plum	Sharp's Early, Formosa, Wickson, Satsuma, Burbank, Blue Imperatrice, Prune-D	Santa Rosa, Grand Duke, Burbank, Green Guage.	Angeleno, Yellow, Pink, Black, Red, Santa Rosa, Satsuma, Black Amber
Peach	Worlds Earliest, Peshawari, July Elberta, Elberta, Quetta	July Elberta, Elberta, Quetta, Pardelux	Henry, Fortynier, Topaz, June Pride, Fairtime, Snow Giant, Fantasia, Red Gold, Honey Kist, Garnem
Apricot	Charmagz, Kaisa, Farmer Early, Gilgiti Sweet, Amba, Quetta	Charmagaz, Kaisha, Gilgiti Sweet, Halman, Rakshey Karpo, Tokpopa, Shakarpara, Nari, Afgani	CITH A-1, 2, 3

Almonds	Seedling origin (unknown varieties)	IXL, Merced, Non Pareil, Makhdoom, Shalimar, Waris, Primorskij,	Non Pareil, Monterey, Carmel, Aldrich, Yorizane, Royal Rosa
Walnut	Seedlings (unknown varieties)	Hamdan, Suleiman, Partap, Govind and Seedling Selections from Kashmir.	CITH Walnut 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, Chandler, Franquette, Ferner

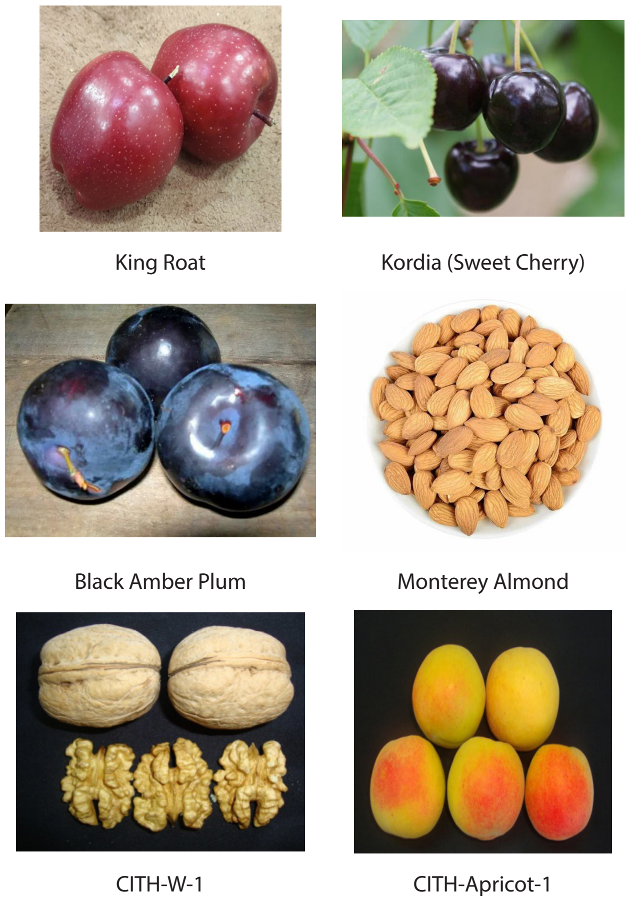

Figure 3: 3rd generation fruit crop varieties with better fruit quality traits and higher yield.

Hybrids

Lal Ambri (Red Delicious x Ambri), Sunehari (Ambri x Golden Delicious), Amred (Red Delicious x Ambri), and Chaubatia Anupam & Chaubatia Princess (Early Shanburry x Red Delicious) developed in India.

Improved Rootstocks for Temperate Fruit Crops

Temperate fruits and nut crops are grown on seedling origin rootstocks. This resulted in the low productivity of fruits and nut crops. These seedling trees have long juvenile period and start bearing after 6 to 7 years in pome and stone fruits and 8-10 years in walnuts with the result, growers got discouraged as they have to wait for long period for their commercial bearing (Tsering Dolkar *et al.,* 2018). But during last 4 to 5 decades a good number of clonal rootstocks have been identified and developed in advanced countries having very short juvenile period (2–3 years) with resistant to biotic and abiotic stresses in various crops and have been recommended for grafting and budding of elite varieties in place of traditional seedling rootstocks, but in India they are yet to be exploited commercially. However, in the advance countries the grafted plants on clonal rootstocks have revolutionized the fruit industry. In view of the importance of these clonal rootstocks and to commercialize their use particularly for high density orcharding and for overcoming biotic and abiotic stresses, their multiplication and distribution has been given a priority and are being multiplied but on very limited scale both by Research Organizations and State Development Departments. Some of the commercially important rootstocks of various crops which are under multiplication along with their salient features is given in Table 13.

Application of Biotechnology in Temperate Fruit Improvement

Plant biotechnological approaches have opened unprecedented opportunities in the field of 'hi-tech' concepts of research with the aim to confront different biotic and abiotic stresses (Lal and Verma, 2022). Since the horticulture is one of the most priority sector, intensive and diversified research on different aspects by employing biotechnological tools can play a vital role in developing improved varieties and their multiplication. Considering the thrust on quality planting material production and distribution of superior cultivars and rootstocks of temperate fruits, micro propagation is one of the best options for achieving the goal. In USA and European countries commercial micro propagation has been developed as an industry but research and development on micro propagation in India, though started late, has progressed to & some extent and many institutions are actively involved in extensive research activities for standardizing protocols for all type of horticultural crops including temperate fruits. Apart from production aspects, screening for quality standards of tissue cultured plants, their stability and potential in the field, identification and incorporation of various elite genes in the existing genotypes for quality as well as biotic-abiotic stress tolerance and human resource development are some of the most important areas for bringing improvement in temperate fruits and have been given priority. To bring improvement in temperate fruits, particularly, apple and walnut, the ICAR and DBT have identified some thrust areas and funding different institutions in temperate region. The

Table 13: Promising rootstocks identified

S. No.	*Crop*	*Rootstocks*	*Salient features*
1	Apple	EMLA 111/ MMIII	Suit to drought prone areas
		EMLA.7	Suit to sloppy, virgin lands, semi vigorous
		EMLA.106/MM.106	Suit to sloppy, and less clay soils, semi vigorous
		EMLA 9/M9	For high density planting with assured irrigation and deep fertile soils, very dwarf
		M 779	For hilly areas of Uttarakhand and H.P.
2	Pear	Quince-A	Standard rootstocks, semi vigorous
		BA .29C	Standard rootstocks, semi vigorous
		Quince - C	Very dwarf
		Quince - B	Semi vigorous
3	Apricot	Apricot seedling	Vigorous, drought tolerant and compatible
		Peach seedling	Suitable for dry and light soils
4	Peach	Peach seedling	Vigorous and compatible
		Gf-557 & gf-677	Drought tolerance
		Siberian-C, Rubia	Dwarf
5	Plum	Wild peach × Apricot seedling	Seedling are vigorous
		Myrobalan-B, Myrobalan-29C, Myrobalan-GF-31, Marigona-2621, GF-8/1	Clonal and semi vigorous, compatible rootstocks
		Pixy × St. Julian. K	Dwarfing rootstocks
		Peach ×Apricot seedlings	Semi vigorous
6	Cherry	Colt	Semi dwarf
		F-12/1	Vigorous
		Mazzard and Mahaleb	Vigorous
7	Almond	Apricot, peach and almond seedlings	Vigorous
		Peach and almond hybrids GF-557×GF-677	Semi dwarfing, good for high density
8	Walnut	Walnut seedlings	Vigorous

Table14: Leading organizations involved in standardization and dissemination of technology on micro propagation of temperate fruits in India

Institution	*Major activities in biotechnology/tissue culture*
Dr. Y.S. Parmer University of Horticulture and Forestry, Solan, H.P.	Micro propagation of apple, peach, kiwi, strawberry and cherry.
Sher-e-Kashmir University of Agricultural Sciences and Technology (K), Srinagar.	Micro propagation of apple clonal root stock, walnut and cherry
University of Kashmir, Srinagar.	Tissue culture of walnut.
G.B.P.U.A.S.T., Pantnagar, Uttarakhand	Tissue culture of pear and peach.
The Energy Resources Institute, New Delhi	Tissue culture of apple and walnut.

activities and progress made in different institutes is detailed in Table 14.

Although, India stands next to China in production of fruits and vegetables, the contribution apple was just 2% to total world production as against 38% by China. In terms of productivity its position is dismal 68th. This warrants immediate short- and long-term biotechnological interventions. Considering the potential of this crop, and to meet growing demand of elite planting material and to bring genetic improvement, DBT in collaboration with ICAR Institutes and other Universities identified some priority areas and partner institutions to enhance productivity in the region (Table 15).

Low Chill Temperate Fruit Crops for Commercial Exploitation in India

Only those cultivars which have low chilling requirement and ability to tolerate high summer temperature should be selected (Bal, 2004; Bist and Yadav, 2004; Dennis, 1997; Dhatt, 2004; Kanwar and Singh, 2004; Mohammad, 2004; Sharpe, 1969; Weinberger, 1956). One of the most successful cultivars is 'Anna' apple, is now extensively grown in areas

Table 15: Priority areas and partner institutions for biotechnological interventions

Priority areas	*Partner Institutions*
Preparation of database on diversity of various cultivars	CITH, Srinagar, NBPGR
Genetic conservation *in-situ* conservation/evaluation	Kashmir University, Y.S. Parmar University, NBPGR, CITH, and IARI, Regional Centre, Amartara Cottage, Shimla
Identification of elite cultivars and rootstocks	CITH, Y.S. Parmar, University and RHRS, Mashobra
Micro propagation	TERI, CITH, Y.S. Parmar University and IHBT, Palampur
Certification for pathogens (viruses and others) and genetic fidelity • Development of diagnostic tools • Other pathogen diagnostics • Resistance to fungicides	IHBT, RHRS, Mashobra and Y.S. Parmar University, Regional Centre
Genetic improvement Short term: Identification of markers for resistance, temperature tolerance/low chilling requirement • Develop linkage maps • QTL maps • Develop mapping populations for breeding Long term- Development of transgenic for disease resistance shelf life / quality traits.	CCMB, Kashmir University, Jammu University, IHBT, TERI, IARI Centre Mashobra, IHBT, Palampur, Y.S. Parmar University and CITH

with limited chilling. The cultivars like 'Sharbati' peach; 'Titron' and 'Kala Amritsari' plum; 'Patharnakh', 'LeConte' and 'Baghugosha' pears became commercially popular in some parts of the subtropical India. A list of important low chill varieties of temperate fruits is mentioned in the table16 for reference purpose.

Current Challenges of the Temperate Fruit Industry

Challenges faced by temperate horticulture cultivation in India are mainly due to the unpredictable weather patterns, including frost, hail, and erratic rainfall, can damage crops and reduce yields.

Pest and disease pressure

Management of pests and diseases like apple scab and codling moth is crucial but challenging without effective control measures.

Limited technology access

Lack of access to modern agricultural technologies hampers productivity and efficiency in cultivation practices.

Infrastructure deficiency

Inadequate post-harvest facilities, storage, and transportation networks contribute to significant losses and reduced profitability.

Water scarcity

Water shortages, especially in regions relying on snowmelt for irrigation, pose challenges to maintaining optimal soil moisture levels.

Land degradation

Soil erosion and degradation threaten long-term productivity, particularly in hilly terrains.

Labour shortages

Seasonal labour shortages during critical stages like harvesting and pruning impact operations and increase costs.

Market instability

Fluctuating prices and lack of market information expose growers to financial risks and uncertainties.

Addressing these challenges requires comprehensive strategies focusing on technology dissemination, infrastructure development, sustainable practices, and market support to ensure the resilience and growth of temperate horticulture in India.

Expansion of cultivation area

There is untapped potential for expanding the cultivation area of temperate fruit crops by identifying and utilizing suitable lands in the Himalayan region. Terraced farming and orchard establishment on marginal lands can help optimize land use and increase production.

Crop diversification and adoption of new varieties

Introducing new varieties of temperate fruits that are better adapted to local conditions can diversify the fruit portfolio and reduce production risks. Research institutions and agricultural universities should focus on breeding high-yielding, disease-resistant cultivars suited to different agro-climatic zones.

Technology adoption

The adoption of modern agricultural practices, such as drip irrigation, fertigation, integrated pest management (IPM), and precision farming, can enhance productivity and resource use efficiency. Training and capacity-building

Table 16: Temperate fruits and their cultivars suitable for cultivation under subtropical climate

S. No.	*Fruit crop*	*Cultivars (*Chilling hours required; value given in bracket indicates the chilling requirement of the respective variety)*
1	Peach (*Prunus persica*)	FlordaGrande (100), Flordabelle (110), Flordared (110), Flordawon (110), FlordaPrince (150), FlordaGlo (150), Tropic Beauty (150), UF Beauty (200), Sunred (210), Flordabest (250), Early Amber (310), Flordasun (310), FlordaKing (350), Flordacrest (350), Gulfking (350), Desert Gold (350), Jewel (350), GulfCrimson (400), GulfPrince (400), Florda Home (400), Bonita (500), May Gold Su (500), GulfCrest (525), FlordaQueen (540), June Gold (650), Parbhat, Pratap, Sharbati, Safeda Early Cream, Saharanpur Prabhat, Shan-i-Punjab, Shaharanpur No. 6, Ranjit Bagh Early, Safeda, Shaharanpur Hybrid 3, Babcock,
2	Nectarine (*P. persica var. nucipersica)*	Sunbest (225), Sunraycer (250), UF Royal (250), UF Queen (250), Sunmist (275), Sundollar, (350), Suncoat (375), Sunred
3	Apple (*Malus domestica*)	Dorsett Golden (250), Anna (300), Tropic Mac (300), Tropic Sweet (300), 88-20 (375), Ein Scheimer (400), 60-39 (400), Tamma, Neomi, Tropic Beauty, Gallia Beauty, Winter Banana, Tame, Vered, HRM99
4	Pear (*Pyrus communis & P. pyrifolia*)	Patharnakh, Gola, Leconte, Keiffer, Smith, Baghugosha, China Pear, Pineapple, Baldwin, Tenn, Flordahome, Ayers Hood, Orient, Carnea, Tsu Li, Ya Li, *P. calleryana* (rootstock requires 400 chilling hours)
5	Strawberry (*Fragaria ananassa*)	Chandler, Tioga, Torrey, Selva, Belrubi, Fern, Pajaro
6	Plum (*Prunus salicina*)	Satluj Purple, Kala Amritsari, Jamuni Meeruti, Titron, Aloo Bokhara, Alucha Black, Titron Howe, Gulfruby, Gulfbeauty, Gulfblaze, Gulfrose
7	Apricot (*Prunus armeniaca*)	New Castle, Early Shipley, St. Ambroise, Benazir, NJ-13
8	Almond (*Prunus dulcis*)	California, Papershell, Hybrid 15, Pathick's Wonder, JKS-55, H-98, Achak (266), Desmayo Largueta (309), Ramillete (326), Marcona (435), Marta (478), Antoneta (514), Ferragnes (558)
9	Sweet Chery (*Prunus avium*)	Stella (200-250), Cristobalina, Temprona del Sot, Precoce de Bernard, Sunburst, Lapin, (Rootstocks - Gisela-5, Mahaleb)
10	Persimmon (*Diospyros kaki*)	Hachiya, Fuiju, Jiro, Hyakuma
11	Olive (*Olea europaea*)	Arbequina, Barnea, Frantoio, Koroneiki, Leccino, Picual, Coratina, Picholine
12	Blueberry *(Vaccinium angustifolium)*	Sharpblue (150), Emerald (200), Jewel (200), Windsor (225), Springhigh (225), Chaucer (400), Woodard (400), Brightwell (400), Climax (450), Tifblue (550), Powderblue (550)

programs should be conducted to educate farmers about the benefits of adopting advanced technologies.

Value addition and market development

Promoting value addition through processing, packaging, and branding of temperate fruits can create opportunities for higher returns and market penetration. Establishing fruit processing units, cold storage facilities, and marketing cooperatives can help reduce post-harvest losses and improve market access for farmers.

Sustainable practices and climate resilience

Implementing sustainable orchard management practices, such as organic farming, soil conservation measures, and water harvesting techniques, can enhance resilience to climate change and environmental degradation. Research on climate-resilient farming practices and crop insurance schemes can mitigate risks associated with climate variability and extreme weather events.

Opportunities in Temperate Fruit Industry

There are increasing opportunities in the temperate fruit industry in India mainly attributed due to higher productivity and farm income potential, huge market demand (domestic and international), Increasing awareness about nutritional value of fruits created round the year demand in every house hold, fast increasing economy improved the purchasing power, ddiversification and optimum utilization of resources/regions, opportunities for small holders, waste land utilization, resilience to climate change and carbon sequestration, scope of processing, packing, storage, value addition and other consumer oriented by-products. Some of priority areas are earmarked below in concise way-

- Higher productivity and farm income
- Huge market demand (domestic and international) due to large number of consumers within the country which has created negative trade deficit.
- Increasing awareness about nutritional value of fruits created round the year demand in every house hold.
- India is the fast-increasing economy resulted in the increase of purchasing power.
- Diversification and optimum utilization of resources/ regions.
- Opportunities for small as well as large holders
- Waste land utilization is only possible through growing

fruit crop trees.

- Fruit crops are comparatively more resilience to climate change and carbon sequestration.
- Larger scope of processing, packing, storage, value addition and transportation are the sectors to provide employment.
- Export and import of the of temperate fruits are a high-income generating sector.
- Employment generator: Need more skilled manpower
- Huge potential in nursery business

Strategies for Improving the Temperate Fruit Industry: A Way Forward Towards Self-reliance

Temperate fruit industry is very dynamic and going through a transformational change through adoption of technological innovation. These technologies are potential to achieve the ever-increasing demand of the domestic market as well as earning the foreign exchange (Kumar and Misger, 2012).

Use of high yielding varieties

New varieties with higher yield and improved fruit quality in temperate fruit and nut crops are the major input affecting the profitability at farm level. Adoption of suitable varieties under high, mid and low zones are pre-requisite for increasing the yield and producing quality fruits and assured supply in the market.

- Adoption of high density orcharding on clonal rootstocks in HDP. – 5 to 10-fold increase
- Diversification in fruit crops (Minor and unutilized fruits)
- Pollination management (apple, pear, plum, cherry, almond, walnut).
- Use of efficient irrigation including fertigation technologies. – inc. 30 to 40%
- Integrated nutrient management with focus on organic farming/biofertilizer application for eco-friendly nutrition as long-term strategy.
- Integrated pest management with focus on biological control & use of biopesticides
- Harvest management practices & post-harvest handling, processing, value addition and scientific storage.
- Production of true to type/certified quality planting material.
- Establishment of bud banks of superior genotypes
- Adoption of modern market management practices

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