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Apricot (*Prunus armeniaca* L.) in Trans-Himalayan Ladakh, India: Current Status and Future Directions

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Abstract: Ladakh is the biggest apricot producer in India with a total production of 15,789 tonnes. The region produced approximately 1,999 tonnes of dried apricot, making it the largest producer of dried apricot in the country. The total area under apricot cultivation is 2,303 ha. Apricots of Ladakh are known for their quality. Historically, the premium quality dried apricots were one of the main trading commodities with neighboring countries. However, the bulk of the apricot produced is consumed locally and only a small quantity is sold outside the region in dried form. The native apricot genotypes of Ladakh possess unique and important characteristics, such as high TSS content, late and extended flowering and fruit maturity, and white seed stone phenotype, which offer opportunity for Ladakh to emerge on the world map for apricot production. However, as of today, the popularity of Ladakhi apricots remains restricted to the region due to limited production, incidence of codling moth (*Cydia pomonella*) and lack of organized marketing system. Critical areas that need focused attention include promotion of premium quality cultivars especially *Halman* and *Raktsey Karpo*, plantation in orchard system, adoption of standard cultural practices, conservation of the rich genetic resource, organic certification, adoption of integrated post-harvest management, management of insect-pests, and establishment of marketing infrastructure.

Keywords: fruit; high altitude; Kargil; Leh; organic

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1. Introduction

Apricot (*Prunus armeniaca* L.) is one of the best-known temperate fruit tree species. It grows in geographically diverse areas ranging from the cold winters of Siberia to the subtropical climate of North Africa and from the deserts of Central Asia to the humid areas of Japan and eastern China. However, areas under commercial production are still very limited (Mehlenbacher *et al.* 1990). Traditionally, apricot has been one of the few temperate fruit trees not affected by over production and often premium prices are reported for both fresh and processed fruits (Hormaza *et al.* 2007). Some apricot cultivars are particularly prone to irregular productions that have been associated with the narrow adaptability range of the species. Indeed, while in other fruit tree species a few cultivars are grown all around the world, in apricot each cultivar is usually restricted to a particular geographical area with certain ecological conditions (Layne *et al.* 1996).

Apricots of Trans-Himalayan Ladakh are known for their quality and the region has not witnessed introduction of cultivars from outside the region. The gene pool is maintained due to geographical isolation and natural high mountain barrier. Historically, the premium quality dried apricots were one of the main trading commodities (Angmo *et al.* 2017). Ladakh is the biggest apricot producer in India. However, the bulk of the apricot produced is consumed locally and only a small quantity is sold outside the region in dried form. However, as of today, the popularity of Ladakhi apricots remains restricted to the region due to limited production, incidence of codling moth (*Cydia pomonella*) and lack of organized marketing system. The disorganized nature of the sector and adherence to certain inefficient production and processing techniques implies that 40-50 percent of the apricot production is wasted. The native apricot genotypes of Ladakh possess unique and important characteristics, such as high TSS content, late and extended flowering and fruit maturity, and white seed stone phenotype, which offer opportunity for exploring the native genotypes for fruit quality breeding programs worldwide (Angmo *et al.* 2017). In view of the uniqueness and premium quality of apricots of Ladakh there is immense scope for Ladakh to emerge on the world map for apricot production. Against this backdrop, the purpose of this review aims to discuss the various aspects of apricot production in Ladakh and to identify scope for further research.

2. World Scenario of Apricot Production

2.1. Fresh Apricot

World annual fresh apricot production was 42,60,466 tonnes during 2017 to 2019 (Table 1). Turkey is a leading country in apricot production with about

20.2% of world's total production. Other important producing countries include Uzbekistan (12.2%), Iran (7.6%), France (7.1%), Italy (6.0%), Algeria (5.5%), Spain (3.8%), Afghanistan (2.9%) and Pakistan (2.8%). These countries produce approximately 68% of the world apricot production. Of the total apricot produced in the world, approximately 12% of the fresh apricots were exported in 2019. Fresh apricot exports have increased by 92.8% from 2010 to 2019. Spain is the global leader in fresh apricot export (21.1%) followed by Suriname (17.0%), Turkey (14.4%), Uzbekistan (10.5%), Italy (7.8%), France (5.2%), Greece (4.9%) in 2018 and 2019. Germany is the world's leading importer, importing 15.3% of all fresh apricot traded in 2018 and 2019. Other important importing countries include Russian Federation (12.9%), Iraq (9.2%), Kazakhstan (8.4%), Pakistan (5.4%), France (5.0%) and Italy (4.5%).

Table 1: Apricot production and area in leading countries (2017-19) (FAOSTAT)

Country	*Production (tonnes)*				*Area under cultivation (ha)*			
	2017	*2018*	*2019*	*Average (%)*	*2017*	*2018*	*2019*	*Average (%)*
World	4796280	3901256	4083861	4260466 (100)	560416	546800	561750	556322 (100)
Turkey	985000	750000	846606	860535 (20.2)	125049	125756	131178	127328 (22.9)
Uzbekistan	532565	493842	536544	520984 (12.2)	41711	38694	43464	41290 (7.4)
Iran	330553	314012	329638	324734 (7.6)	54346	52480	56090	54305 (9.8)
France	654938	112890	134800	300876 (7.1)	12197	12280	12280	12252 (2.2)
Italy	266372	229020	272990	256127 (6.0)	17363	17809	17910	17694 (3.2)
Algeria	256890	242243	209204	236112 (5.5)	44307	35500	30861	36889 (6.6)
Spain	162872	176289	145830	161664 (3.8)	21002	20567	20240	20603 (3.7)
Afghanistan	131816	109086	129363	123422 (2.9)	13413	10908	17719	14013 (2.5)
Pakistan	141721	107986	104743	118150 (2.8)	22715	18629	19372	20239 (3.6)

2.2. Dried Apricot

Global annual dried apricot export is estimated at 1,62,635 tonnes in 2018 and 2019 (Table 2). Dried apricot exports have increased by 21.5% from 2010 to 2019. Turkey is also the biggest dried apricot exporter. In 2018 and 2019 it exported an average of 97,033 tonnes of dried apricot, which correspond to 59.7% of the total world export (FAOSTAT). Other important countries exporting dried apricot include Afghanistan (14.9%), Tajikistan (6.7%), Uzbekistan (5.1%), Kyrgyzstan (3.9%), Belarus (2.4%), Spain (2.3%), Netherlands (1.0%), France (0.9%) and Germany (0.8%). USA is the world's leading importer of dried apricot, importing 9.5% of all dried apricot traded in 2018 and 2019 (Table 3). Russia Federation is the second leading importer, importing 8.7% of dried apricot in 2018 and 2019 (FAOSTAT).

Table 2: Leading apricot exporting countries in 2018-19 (FAOSTAT)

Country	*Fresh apricots (tonnes)*			*Dried apricots (tonnes)*			
	2018	*2019*	*Average (%)*	*Country*	*2018*	*2019*	*Average (%)*
World	467943	492017	479980 (100)	World	181355	143915	162635 (100)
Spain	109297	93379	101338 (21.1)	Turkey	93797	100270	97033.5 (59.7)
Suriname	89327	73495	81411(17.0)	Afghanistan	43693	4774	24233.5 (14.9)
Turkey	70698	67631	69164.5 (14.4)	Tajikistan	10904	-	10904 (6.7)
Uzbekistan	42664	58024	50344 (10.5)	Uzbekistan	7453	9035	8244 (5.1)
Italy	26603	48161	37382 (7.8)	Kyrgyzstan	4124	8602	6363 (3.9)
France	28276	21768	25022 (5.2)	Belarus	3673	4160	3916.5 (2.4)
Greece	23931	23017	23474 (4.9)	Spain	5057	2478	3767.5 (2.3)
Afghanistan	782	18136	9459 (2.0)	Netherlands	1649	1669	1659 (1.0)
Jordan	5816	11117	8466.5 (1.8)	France	1354	1570	1462 (0.9)
Serbia	1661	8548	5104.5 (1.1)	Germany	1078	1419	1248.5 (0.8)

Table 3: Leading apricot importing countries in 2018-19 (FAOSTAT)

Country	*Fresh apricots (tonnes)*			*Dried apricots (tonnes)*			
	2018	*2019*	*Average (%)*	*Country*	*2018*	*2019*	*Average (%)*
World	392620	406826	399723 (100)	World	138936	140461	139698.5 (100)
Germany	59930	62242	61086 (15.3)	USA	13970	12530	13250 (9.5)
Russia Federation	52999	50368	51683.5 (12.9)	Russia Federation	10766	13470	12118 (8.7)
Iraq	37672	35863	36767.5 (9.2)	France	8671	8704	8687.5 (6.2)
Kazakhstan	30102	36663	33382.5 (8.4)	UK & N. Ireland	9985	7577	8781 (6.3)
Pakistan	25369	17831	21600 (5.4)	Germany	7268	7277	7272.5 (5.2)
France	22653	17100	19876.5 (5.0)	Iraq	8456	5906	7181 (5.1)
Italy	20141	16140	18140.5 (4.5)	Kazakhstan	8817	4095	6456 (4.6)
Austria	13469	15404	14436.5 (3.6)	China, mainland	4629	6772	5700.5 (4.1)
Poland	9858	12869	11363.5 (2.8)	Ukraine	4564	5694	5129 (3.7)
UK & N. Ireland	9418	9806	9612 (2.4)	Belarus	4788	5520	5154 (3.7)
Czechia	7641	10667	9154 (2.3)	India	5748	4143	4945.5 (3.5)
Saudi Arabia	8380	9256	8818 (2.2)	Brazil	4506	4421	4463.5 (3.2)

3. Apricot in Ladakh: Current Status

Ladakh is the biggest apricot producer in India with a total production of 15,789 tonnes in 2019. The fruit crop is a major source of livelihood and is also deeply associated with the tradition and culture of the region. Apricots of Ladakh are known for their quality and the region has not witnessed introduction of cultivars from outside the region except for trial purposes. Historically, the

premium quality dried apricots, locally known as *Phating*, with high sugar and dry matter content, were one of the main trading commodities. *Raktsey Karpo*, apricots with white seed stone, is unique to Ladakh. It is the most preferred cultivar for fresh consumption (Naryal *et al.* 2019a). However, as of today, the popularity of Ladakhi apricots remains restricted to the region due to limited production, incidence of codling moth and lack of organized marketing system.

Apricot, locally known as *Chuli*, is classified in Ladakh into two broad categories based on kernel taste. Fruits with bitter kernel are called *Khante* meaning bitter, while those with sweet kernel are called *Ngarmo* meaning sweet (Targais *et al.* 2011). The *Ngarmo* is further divided into two sub-groups based on seed stone color. Fruit with white seed stone is called *Raktsey Karpo*, while those with brown seed stone are called *Nyarmo*. Large size fruits are called *Chenmo* meaning large, while those with small size are called *Chun* meaning small. Apricots with white seed stone are unique to Ladakh, and are associated with sweet kernel, brightly colored fruit with high TSS (Angmo *et al.* 2017). Oil extracted from the sweet kernel is used for edible purpose either in pure form or mixed with walnut oil. A spoonful of oil is mixed with finely grinded roasted barley flour, salted tea and sugar to prepare a local dish called *Phemar* which is served to guests and during festive occasion like marriage ceremony. The bitter kernel is used for extraction of oil which has religious, cosmetic and medicinal values. Even today, the oil is used as hair oil and is known to relieve backache and joints ache. The oil is popular as body oil and massage oil and is known for its ability to penetrate the skin without leaving an oily feel. Applying warm apricot oil mixed with a pinch of common salt on chest is known to give relief to patients with acidity (Targais *et al.* 2011).

3.1. Genetic Diversity

High morphological diversity is observed in Ladakh (Figure 1). Fruit weight ranged from 5.3-52.5 g (Naryal *et al.* 2020). Evaluation of 162 apricot genotypes collected from nine locations showed marked variability in TSS content ranging from 10.7-37.6º Brix with average value of 20.7±5.1 (Naryal *et al.* 2020). Evaluation of 65 apricot genotypes at a single location showed wide variation in fruit weight ranging from 7.1-53.7 g with mean weight of 21.6±9.3 g. The evaluated genotypes showed high TSS content ranging from 11.0-37.9 with mean value of 23.9±5.7º Brix (Angmo *et al.* 2017). Kumar *et al.* (2009) studied genetic variability of apricots of 36 genotypes from nine sampling sites from Nubra and Leh valley. The study suggested high genetic diversity in apricot grown in the region. Analysis of molecular variance (AMOVA)

Figure 1: Morphological diversity of Trans-Himalayan Ladakh apricots

based on RAPD and ISSR combined data suggested more variation within the population (72%) as compared to among valley (15 %) and among population (13%).

3.2. Area and Production

3.2.1. Area under Cultivation

The area under apricot cultivation in Kargil and Leh district is shown at Table 4. The total area under apricot cultivation is 2,303 ha (Kargil: 1,645 ha; Leh: 658 ha) in 2019. The area under apricot cultivation has increased by 9.4% in Kargil district and decreased by 16.9% in Leh district from 2015 to 2019. The decrease in area under apricot cultivation in Leh district is due to dying of plants in flood affected areas.

Table 4: Area under apricot cultivation in Ladakh (ha) (2015-19)

District	*Zone*	*2015*	*2016*	*2017*	*2018*	***2019***	***Average (%)***
Kargil	Kargil	798	807	809	812	864	818 (52.6%)
	Batalik	465	466	491	495	506	485 (31.2%)
	Chicktan	240	241	255	255	275	253 (16.2%)
	Total	1503	1514	1555	1562	1645	1556 (100%)
Leh	Khalsi	444	444	314	330	315	369 (53.2%)
	Saspol	78	78	38	45	99	68 (9.8%)
	Leh	105	105	59	79	61	82 (11.8%)
	Kharu	19	19	12	18	14	16 (2.3%)
	Nubra	146	146	149	182	169	158 (22.8%)
	Total	792	792	572	654	658	693 (100%)
Total		**2295**	**2306**	**2127**	**2216**	**2303**	2249

3.2.2. Number of Apricot Trees

The number of apricot trees in the region under fruit bearing stages is shown at Table 5. There are approximately 3,74,482 trees. The number of trees in the fruit bearing stage has increased by 97.5% in Kargil district and only 1% in Leh district from 2015 to 2019.

Table 5: Number of fruit bearing apricot trees in Ladakh (2015-19)

District	*Zone*	*2015*	*2016*	*2017*	*2018*	*2019*
Kargil	Kargil	66227	66428	66600	120739	129383
	Batalik	38591	38358	40433	73530	75779
	Chicktan	19918	19838	21010	37984	41213
	Total	124736	124624	128043	232253	246375
Leh	Khalsi	70358	70658	69927	70080	71568
	Saspol	9750	9843	8244	8480	9382
	Leh	12890	12684	12389	12480	13601
	Kharu	1870	1688	1688	1713	2578
	Nubra	31900	30655	29913	30512	30978
	Total	126768	125528	122161	123265	128107
Total		**251504**	**250152**	**250204**	**355518**	374482

3.2.3. Production of Fresh Apricot

Ladakh produces approximately 15,789 tonnes of fresh apricot, making it the largest producer of apricot in the country. The fresh apricot production in Kargil and Leh districts are shown at Table 6. The fresh apricot production has increased by 3.8-fold in Kargil district and 1.6-fold in Leh district during 2015 - 2019.

Micro-climate plays an important role in production of apricots that possess characteristics features for fresh consumption. In general, villages that

are located above 9,500 feet elevation produce the best quality fresh apricots. It has been shown that fruit sweetness increases with increasing altitude.

Table 6: Fresh apricot production in Ladakh (tonnes) (2015-19)

District	*Zone*	*2015*	*2016*	*2017*	*2018*	*2019*	*Average (%)*
Kargil	Kargil	1289	2987	4045	5075	6375	3954 (59.9%)
	Batalik	50	41	2455	2555	2750	1570 (23.8%)
	Chicktan	402	747	1276	1403	1531	1072 (16.3%)
	Total	1741	3775	7776	9033	10656	6596 (100%)
Leh	Khalsi	1787	542	542	1850	2910	1525 (46.3%)
	Saspol	314	195	195	481	384	314 (9.5%)
	Leh	425	603	603	640	451	544 (16.5%)
	Kharu	76	118	118	260	107	136 (4.1%)
	Nubra	587	466	466	1068	1281	774 (23.5%)
	Total	3189	1924	1924	4299	5133	3294 (100%)
Total		**4,930**	**5,699**	**9,700**	**13,332**	**15,789**	9,890

3.2.4. Production of Dried Apricots

The dried apricot production in Ladakh is shown at Table 7. Ladakh produced approximately 1,999 tonnes of dried apricot in 2019, making it the largest producer of dried apricot in the country. The dried apricot production has increased by 6.1-fold in Kargil district and no significant increase was observed in Leh district from 2015 to 2019.

Table 7: Dried apricot production in Ladakh (tonnes) (2015-19)

District	*Zone*	*2015*	*2016*	*2017*	*2018*	*2019*	*Average (%)*
Kargil	Kargil	160.0	370.7	501.6	628.1	790.5	490.2 (59.9%)
	Batalik	5.2	4.9	303.4	316.8	341.0	194.3 (23.8%)
	Chicktan	49.9	93.6	158.4	174.0	189.7	133.1 (16.3%)
	Total	215.1	469.2	963.4	1118.9	1321.2	817.6 (100%)
Leh	Khalsi	235.9	73.2	70.5	240.5	384.1	200.8 (44.3%)
	Saspol	40.8	71.5	70.6	63.5	51.0	59.5 (13.2%)
	Leh	56.5	79.5	78.6	84.5	59.7	71.8 (15.9%)
	Kharu	10.3	15.6	13.5	34.2	14.2	17.6 (3.9%)
	Nubra	76.3	62.0	61.5	141.0	169.0	102.0 (22.6%)
	Total	419.8	301.8	294.7	563.7	678.0	451.6 (100%)
Total		**634.9**	**771.0**	**1258.1**	**1682.6**	1999.2	1269.2

Not all parts of Ladakh produce premium quality dried apricots. Micro-climate plays an important role in production of apricots that possess characteristics of quality dried fruits. In general, villages that are located in narrow valleys below 9,500 feet elevation produce the best quality dried apricots. Villages that are known for producing premium quality dried apricots (Halman/*Phating*) in Kargil district are Hardaz, Karkichu, Majidas, Kharul, Hundurmal, Shilikchay, Gongma Kargil, Manjee, Batalik, Chulichan, Gurgurdo, Sanatsey, Hordas, Garkhon, Darchik, Sanjak and Dargo. Similarly, in Leh district the villages known for producing premium quality dried apricots are Dha, Biama, Hanu Thang, Achinathang, Lehdo, Skurbuchan, Domkhar-Dho, Takmachik, Turtuk, Bokdang and Thang.

3.3. Propagation

There is a growing interest in the vegetative propagation of apricots primarily due to an increasing commercial demand for the plant. Vegetative propagation through budding and grafting are the methods of choice for propagation. Methods have been standardized for propagation through budding in the region. Shield budding performed in mid-August was found to be a superior method of propagation as compared to patch budding and T-budding (Dwivedi *et al.* 2000a). Chip-budding performed in the last week of February was found to result in over 70% salable plants (Dwivedi and Singh, 2001). Tongue and cleft grafting performed in the first week of February is recommended as method of choice for propagation of apricots through grafting (Dwivedi *et al.* 2000b).

3.4. Apricot Drying

Sun drying of apricot fruit is the oldest form of preservation technique known to the people of Ladakh and is still practiced on a large scale (Hussain *et al.* 2014). Majority of the apricot fruit is dried using the traditional method in the open sun. However, the traditional method of open sun drying is prone to spoilage due to incorrect picking methods, unhygienic and non-controlled drying procedures. The fruits are generally sun-dried on the roof of houses or on open fields before it is sold off in local markets with very little value addition. The major disadvantage of traditional drying is the visual appearance of the fruits as the apricots dried with this method can be susceptible to rapid darkening and decomposition of chemical structure that leads to objectionable changes in color, texture, and flavor that fetches very low prices in the market. It is due to the suboptimal drying practices that the dried fruits of Ladakh have a limited access to other markets. Of late, some small-scale solar apricot dryers such

as tent dryer, solar cabinet dryer, solar polyhouse dryer, sunbest solar dryer, metallic solar dryer, PEN solar dryer have been installed by several agencies in Ladakh (Hussain *et al.* 2014). However, due to their small size, growers are finding it difficult to achieve quality dried fruits at commercial scale.

Mir *et al.* (2009) studied the effect of sulphiting and drying methods on physico-chemical and sensorial quality of dried apricots during ambient storage. It was found that KMS pre-treatment at concentration of 6% for 60 minutes prior to drying significantly improved and maintained the quality of dried apricots for up to 12 months of ambient storage. Solar tunnel drying was found to produce hygienic products and reduced the drying time to 3-4 days compared to 14-16 days in open air drying.

3.5. Value Added Products

A small quantity of processed products such as jam, juice and seed oil are produced by few privately-owned firms. However, less than 50 tonnes of apricot pulp are being used for product development, and are locally consumed. There is ample scope to increase the market share of locally produced apricot-based value added products.

3.6. Nutrient and Bioactive Content

Kernel: Proximate analysis of the bitter kernels showed presence of 45.5-54.2% fats, 17.8-22.6% protein, 21.2-35.3% carbohydrate, 0.8-4.7% crude fiber and 6-22.2% dietary fiber (Dwivedi and Ram, 2008). Naryal *et al* (2019b) studied amygdalin content in apricot kernel. Bitter kernels contain significantly higher amygdalin (44.6±9.0 $mg.g^{-1}$) than that of sweet kernel (3.1±1.8 $mg.g^{-1}$). Korekar *et al.* (2011) studied total phenolic content (TPC) and antioxidant capacity of apricot kernel. The kernel was found to be rich in TPC ranging from 92.2 to 162.1 mg gallic acid equivalent /100 g. The free radical-scavenging activity in terms of inhibitory concentration (IC_{50}) ranged from 43.8 to 123.4 mg/ml and ferric reducing antioxidant potential (FRAP) from 154.1 to 243.6 $FeSO_4.7H_2O$ µg/ml. The study underlines the important role played by genetic background for determining the phenolic content and antioxidant potential of apricot kernel.

Dried fruit: Analysis of fruit sugar content in dried fruit samples from 108 apricot genotypes showed marked variability and ranged from 314.5±32.1 to 598.8±43.8 mg/g DW. Sucrose is the highest individual sugar (57.8%), followed by glucose (19.4%), fructose (14.3%) and sorbitol (8.4% of total sugar) (Naryal *et al.* 2019c).

4. Uniqueness of Ladakhi Apricots

Apricots of Ladakh are known for its quality. Historically, the premium quality dried apricots were one of the main trading commodities with neighboring countries. *Phating*, the premium quality dried apricots of Ladakh, are popularly known as *Nyari Khambu* in Tibet. Uniqueness of the apricots of Ladakh was recently documented and the same have been recognized by the scientific community as evident from publications of the studies in peer-reviewed journals.

4.1. Raktsey Karpo is Unique to Ladakh

Raktsey Karpo, apricots with white seed stone, is unique to Ladakh. It has not been reported from anywhere else in the world. White seed stone phenotype is associated with sweet kernel, brightly coloured fruit with high TSS content (Angmo *et al.* 2017).

4.2. Raktsey Karpo is most Preferred by Consumers

Raktsey Karpo is most preferred by the consumers for fresh consumption. It ranked first in terms of sweetness, juiciness, aroma, flesh color and overall appreciation (Naryal *et al.* 2019a).

4.3. Raktsey Karpo is Rich in Sorbitol

Raktsey Karpo contains significantly higher sorbitol (53.6±26.5 mg/g DW) followed by fruits with brown coat with sweet kernel (34.6±27.0 mg/g DW) and fruits with brown coat with bitter kernel (23.8±36.1 mg/g DW) (Naryal *et al.* 2019c). Sorbitol is a sugar alcohol that is used as a sweetening agent in various food products such as sugar-free sweets and chewing gum.

4.4. Identifiable Marker for Quality

The white seed coat phenotype of *Raktsey Karpo* can be considered an easily identifiable marker for quality fruit. The phenotype can be explored as a distinguishing feature of high-quality apricots of Ladakh. It can be used to develop consumer's loyalty and strong image of apricots of Ladakh (Angmo *et al.* 2017).

4.5. Fruit TSS Increase with Increasing Altitude

Apricots of Ladakh are sweeter. The sugar content in terms of total soluble solids (TSS) ranged from 11.0-37.9ºBrix with mean value of 23.9±5.7ºBrix. Altitude showed linear relationship with fruit TSS content. For every 100 m

increase in elevation, the fruit TSS increased by 1.2ºBrix. *Raktsey Karpo* has significantly higher TSS (28.1±3.8ºBrix) than cultivars with brown seed coat (Angmo *et al.* 2017).

4.6. Fruit Sugar Increase with Increasing Altitude

High altitude environmental conditions contribute to the sweetness of the apricot of Ladakh. Linear relationship between sugar contents and increasing altitude has been observed. For every 100 m increase in altitude, total sugar contents increased by 64.8 mg/g DW. For every 100 m increase in altitude, sucrose contents increased by 49.1 mg/g DW. Fruit sorbitol contents showed linear relationship with increasing altitude. Sorbitol contents increased by 11.9 mg/g DW for every 100 m increase in altitude. Therefore, high altitude climatic conditions are favorable for production of apricots with high sugar contents (Naryal *et al.* 2019c).

4.7. Small Fruit

Apricots of Ladakh are small. Fruit weight ranged from 7.1-53.7 g with mean weight of 21.6±9.3 g. For every 100 m increase in elevation the fruit weight decreases by 0.5 gm (Naryal *et al.* 2020).

4.8. Late Fruit Ripening

Apricots of Ladakh are late maturing as compared to apricots from other parts of the world. The fruits are harvested between mid-July and early September. For every 100 m increase in elevation, fruit ripening is delayed by 7.1 days. Therefore, apricots of Ladakh region have comparative advantage as it does not coincide with the main apricot season in the market (Naryal *et al.* 2020).

4.9. Extended Fruit Ripening

The harvesting season of apricots of Ladakh remained for 39 days in an orchard at DIHAR Leh. Harvesting spanning more than a month is an important element in view of short shelf life of fresh apricot fruit. Therefore, apricots of Ladakh can be marketed over an extended period.

5. Value Chain of Apricots in Ladakh

5.1. Value Chain Mapping and Actors

The value chain of apricot in Ladakh is presented in Figure 2. Overall, the existing value chain mainly comprises of individual growers, input suppliers, processors, manufacturers, retailers, Directorate of Horticulture, NGOs and research institutes.

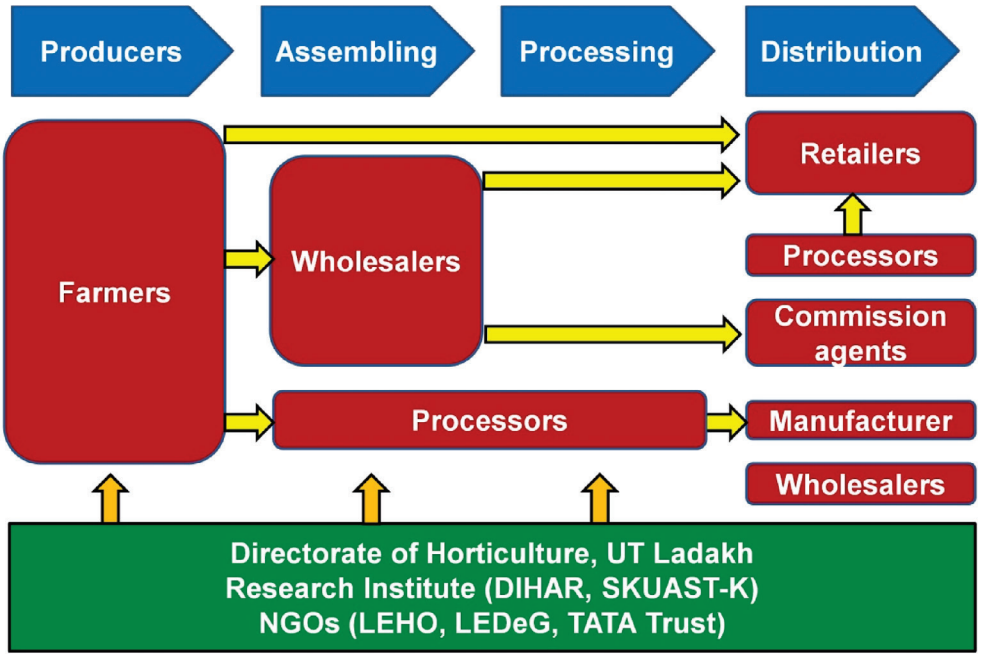

Figure 2: Value chain of apricots in Trans-Himalayan Ladakh region

5.2. Actors and Roles

Farmers: Individual farmers grow and harvest apricots. They sell fresh apricots (*Raktsey Karpo* and *Halman*) @ Rs 130-220 per kg to retailers. They also dry apricot fruits at small scale, and sell the fresh and dried apricots directly to the consumers or to retailers and wholesalers.

Wholesaler: Wholesalers are among the most important actors in the value chain. They visit the apricot growing villages after the harvest season, mostly in September-October, and procure the majority of the dried apricots and sweet kernel directly from the growers. They pay Rs 250-350 per kg for *Phating* and Rs 300-450 per kg of sweet kernel. The wholesalers usually operate a retail store in the local market and trade in several agri-food products, e.g. apricot, walnut, apple and almond. Through them a small quantity of dried apricot is also sold outside the region.

Retailers: Retailers procure apricot directly from farmers or through wholesalers. They do the packaging and sell dried apricots mostly in packs of 500 g or 1 kg. They sell fresh apricots (*Raktsey Karpo* and *Halman*) @ Rs 400-450 per kg, and dried apricot (*Phating*) @ Rs 600-800 per kg. Municipal Committee of Leh town has made some special provisions, which lets some of the local vendors sell dry fruits on the footpaths in the main market. Dry fruit vendors

and farmers (mainly women) selling fresh vegetables on the pavement are distinguishing features of the Leh market.

Processors: Processors are important actors in the value chain. They purchase low-quality apricots directly from the growers. They carry out primary processing of apricots and sell pulp and seed oil to manufacturers or commission agents. Besides processing fresh apricots, they also undertake development of value-added products such as juice, squash and jam.

Directorate of Horticulture: Directorate of Horticulture is the main agency involved in promotion of apricot plantation and development of its value-added products. Recently the Directorate in collaboration with National Institute of Solar Energy (NISE) has developed a Solar Apricot Dryer (capacity 70 kg per batch). The process for installing a total of 630 dryers on farmers' fields in Leh and Kargil district has begun in 2019.

Non-governmental organizations (NGOs): NGOs such as LEHO, LEDeG and TATA Trust are actively involved in demonstration of technologies for hygienic drying of apricots in selected villages. The interventions by LEHO in Takmachik village serve as a model for other villages.

Input supplier: The supply of inputs such as nursery plants, farm tools and agrochemicals are being done primarily through the Horticulture Department in Kargil and Leh. Few privately owned nurseries and input suppliers have opened shops in Kargil and Leh.

Research institutes: Research institutes, particularly DRDO-DIHAR and SKUAST-K, play an important role in the value chain. The institutes conduct regular training sessions to the farmers. Both the institutes played key roles in successful management of yellow tail moth (*Euproctis similis*) on apricot in Leh district during 2016-18.

6. Major Insect Pests and Diseases of Apricots in Ladakh

Ladakh region is known for its low incidence of insect-pests and diseases, which can be partly attributed to low humidity, extreme cold winter, low cropping intensity and diversified cropping system. Aphid is a regular pest of apricot in Ladakh. However, in 2016 there was an outbreak of the pest causing a huge economic loss. Codling moth is a serious insect-pest of apricot in Ladakh. In recent years, severe infestation of yellow tail moth (*Euproctis similis*) on apricot trees was seen in Dah-Hanu and Sham belts (Stobdan *et al.* 2019).

6.1. Aphid

Aphid is a regular pest of apricot in Ladakh. The pest is not known to cause a big damage to apricots in the region. However, in 2016 there was an outbreak

of the pest causing a huge economic loss to the major apricot growing belt of Leh district, particularly in Sham and Turtuk belt. Aphid infestation on apricot in 2016 alone resulted in a loss of Rs 545 lakhs in Leh district. The pest infestation was particularly severe on *Halman* cultivars as compared to others. It damages floral and vegetative buds by sucking sap due to which unfolding leaves curl up, remain stunted, get distorted and later turn pale. Consequently, fruit-set is poor with a pre-mature fruit drop and forming of sub-normal fruit. Severely infected ones get their leaves curling inwards, and eventually dry out and shed.

6.2. Codling Moth

Codling moth (*Cydia pomonella*) is a serious insect-pest of apple and apricot in Ladakh. The pest is widely distributed in fruit growing areas of Ladakh. It is the most persistent, destructive and difficult to control pests of fruit crops in Ladakh. To avoid and restrain its spread to other parts of the country the Government has imposed restrictions under SRO 47 dated 25th February 2008 under the Jammu and Kashmir Plant Diseases and Pests Act 1973, on the movement of plants and fruit of apple, apricot and walnut from Ladakh.

6.3. Yellow Tail Moth

Yellow tail moth (*Euproctis similis*) is not a regular insect-pest of fruit crops in Ladakh. However, it emerged as a major pest of apricot during 2013-2016 in Dha-Hanu and Sham belt of Leh district. The caterpillar causes extensive defoliation to host trees through feeding activities, leading to reduced growth and complete destruction of fruits.

The infestation of the insect caused a severe loss over 80% in income for the villagers in Dah-Hanu belt during 2013-16. Monetary loss due to the insect in affected five villages in Leh district alone has been estimated to Rs 232.6 lakhs in 2016. This is a huge economic loss. Besides apricot, the insect was also found feeding on apple, peach, rose, poplar and willow. The hair on the caterpillar causes skin rashes and respiratory problems among the villagers. Local inhabitants perceived the severe infestation as a result of climate change and disrespect of local deities. If appropriate control measures were not taken, the pest had the potential to destabilise the entire apricot industry of the region. The pest has been successfully managed in Leh district and no incidence has been observed since 2019 (Stobdan *et al.* 2019).

Outbreak of yellow tail moth, which is previously unknown to the farmers of Ladakh, and its subsequent control within a short time frame may serve

as a model for management of major insect-pests of apricot in the region. Management of established pests such as codling moth and aphids can also be dealt with in mission mode through collective sharing of responsibilities as has been done in integrated management of yellow tail moth (Stobdan *et al.* 2019).

6.4. Gummosis

Gummosis is a major problem of stone fruits in cold desert condition. Exudation of gum from the stem and branch loosen the bark causing secondary infection leading to drying of branches in severe cases. The causal factor could be biotic such as fungi and bacteria (*Pseudomonas syringae*) or may be due to abiotic factors. For management of the disease, scarification of gumming area with sharp knife in spring followed by application of Mashobra paste is effective. Foliar spray of streptocycline (0.01%) plus copper oxychloride (0.2%) is effective to overcome gummosis (Dwivedi *et al.* 2007).

7. Future Directions

Significant progress has been made in promoting apricot production and drying in Ladakh. Major focus has been on growing *Halman* and *Raktsey Karpo* cultivars and solar drying of fruits. The following priority areas need a focus attention in coming years:

Cultivars: Majority of the trees are seedling origin. There is a need for promotion of premium quality cultivars especially *Halman* and *Raktsey Karpo*.

Fruit nursery: Supply of quality nursery plants of known cultivar is vital for promotion of apricot in the region. So far, the majority of the apricot plant is procured through informal farmer-to-farmer contact. To get uniformity in products, fresh as well as dried, it is important to grow known cultivars on s large scale. Mass propagation of a selected mother tree is laborious and time consuming by the traditional grafting technique. Adoption of tissue culture technology for multiplication of selected mother trees on a large scale will bring quick results.

Orchard system: Apricot trees are planted around the houses of the farmers or around the field boundaries. The orchards are poorly managed and scattered over a large area. Well managed apricot orchards are hard to find in the region. There is a need for plantation of apricot trees in the orchard system. Studies suggested that increased density reduces yield per tree but augment yield per hectare.

Creation of water resources: Assured irrigation is a must for fruit tree cultivation in Ladakh. Hot and dry conditions result in high evaporation rates

in Ladakh. The soil is mostly sandy loam with very less moisture holding capacity. Hence, the crops need more water with higher frequency. Creation of water resources is a must in the region for apricot plantation.

Training and pruning: Standard cultural practices such as pruning and training of trees are not performed in Ladakh. Lack of training and pruning resulted in trees reaching heights that hinder fruit harvesting. Besides, the fruits remain small and low quality. There is a need for an intense awareness campaign on the need of training and pruning. Farmers need to be taken on exposure tours to show orchards where trees are regularly trained and pruned. Front line demonstrations need to be conducted in every village.

Application of manure and fertilizer: The fruit trees are hardly applied any manures and fertilizers resulting in low productivity and small fruit size. Importance and method of application of manure to apricot trees need to be communicated to the growers. Front line demonstrations on application of fertilizers need to be conducted in every village.

Slow plant growth: The growth of plants, especially at early stage, is slow in Ladakh due to low temperature. Application of black plastic mulch while establishing new orchards need to be promoted. Mulching reduces the time for fruit trees to reach the fruit bearing stage almost by half. Besides, use of mulching significantly reduced the number of irrigation. Growers should be demonstrated the effect of plastic mulching on growth and fruiting. Front line demonstrations on application of mulching technology need to be conducted in every village.

Planting season: Apricot nurseries are planted in March and April when the plants are in dormant stage. Planting after leaf emergence results in high mortality rates due to transplanting shock. Use of Polybag technique needs to be promoted for extending the planting season and for achieving higher success rate.

Field gene bank: Ladakh is rich in genetic resources of apricots. Trees yielding low quality fruits are often uprooted to make space for cultivars producing high quality fruits. Besides, house constructions, the road widening works often results in uprooting apricot trees. There is a need to conserve the rich genetic resources of the region.

Organic certification: Apricots are being grown in the region in a traditional way without the use of chemical fertilizer and pesticides. There is a need to certify and promote apricots of Ladakh as organic.

High wastage rates: The disorganized nature of the sector and adherence to certain inefficient production and processing techniques currently result in

wastage of approximately 40-50 percent of the apricot produced in Ladakh. There is a need to adopt integrated post-harvest management and establish marketing infrastructure for apricots.

Harvesting tools: Currently apricot fruit are harvested by shaking or beating the branches, which results in a high wastage rate. Although SKUAST-K Leh has developed a low cost apricot harvest net, there is a need for interventions to mechanized harvesting to improve harvesting efficiency and retain quality of harvested fruits.

Integrated post-harvest management: Ripe apricot fruit is delicate and needs to be processed as soon as possible. There is a need for integrated post-harvest management of apricots, which is currently lacking in the region.

Establishment of marketing infrastructure: Apricot is locally consumed and lacks a marketing system for trading outside the region. There are opportunities for fresh as well as processed products from Ladakh to be sold in down-country supermarkets. There is a need for establishment of marketing infrastructure for fresh and processed apricots of Ladakh.

Hygienic drying: Majority of the apricot fruit is dried in open under the sun, which is prone to spoilage due to incorrect picking methods, unhygienic and non-controlled drying procedures. There is a need to develop a systematic fruit collection, processing, drying and marketing in the region.

Area expansion: Agriculture production in Ladakh is entirely based on irrigation. The main constraints in area expansion under fruit tree plantation is the assured water source for irrigation. There is immense scope to expend the area under apricot cultivation from the existing 2303 hectares. The vast area of barren land remains unused. With technological advancement, it is now feasible to lift water from the river for irrigation. The glacial water that drains into the rivers can be conserved and judiciously used to bring more area under cultivation. There is a range of technologies available for improved operation, better management and efficient use of irrigation water.

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