CHAPTER 1

INTRODUCTION

APRICOT

Apricot (*Prunus armeniaca* L., Rosaceae) is the 3rd most economically important stone fruit crops in the world [1], [2]. The annual production of apricots is about 4.26 million metric tons in 2017. Turkey, Iran, Uzbekistan, Algeria, and Italy are the top five apricot producing countries in the world. India ranked 30th among the top apricot producing countries, and the production volume was 15.07 thousand metric tons in 2016. The apricot tree grows up to 7-10 m height and has a spreading and dense canopy. Leaves are ovate, finely serrated and pointed at the tip. Flowers bloom in a cluster in early spring before the leaves, with 5-petaled whitepink coloured flowers. A long period of subzero temperatures forces the apricot tree to remain in a dormant condition. Dormant buds get sprouted on the onset of spring, and fruit is harvested in late summers [3].

Figure 1.1: Dormant apricot trees at Takmachik village in trans-Himalayan Ladakh (a); apricot in full bloom in Ladakh (b); apricot flower (c); and apricot fruit (d)

1.1 Origin and distribution

Apricot is believed to originate from Armenia and hence named as *armeniaca*. However, according to Vavilov [4] apricot has three main centers of origin: (1) Chinese centre of origin which includes mountainous region of Central and Western China, (2) Central Asiatic centre of origin that comprise Uzbekistan, Tajikistan, Afghanistan, North west India and Pakistan, Xinjiang province of China, and (3) Near-Eastern centre of origin which includes interior of Asia Minor, Iran, Transcaucasia and Turkmenistan.

There are three distinct perspectives on the spread of apricot from Central Asia to the rest of the world. The 1st view is that dried fruits and stones in Fergana Valley (border of Tajikistan, Uzbekistan, and Kyrgyzstan) were brought to Anatolia by soldiers of Great Alexander in BC 334 to Transcaucasia and Iran [5]. The 2nd view is that apricot was moved to Anatolia through Silk Road from Central Asia and China by the merchants, and later carried to Italy by Roman soldiers [6]. The 3rd view is that during 2 BC Romans took apricot with them to the west during their expeditions to Near East (Caucasus, Iran, and Syria) [5]. In 1524 or 1548 apricot was moved to England from Italy [7]. Apricot was taken to America continent in 1626 by the Spanish.

1.2 Apricot in trans-Himalayan Ladakh

Apricot is a hardy and important tree which grows in the dry and temperate climate of North-western Himalayas. Apricots are known for their quality in trans-Himalayan Ladakh. Because of High Mountain as a natural barrier and geographical isolation this region has not reported the introduction of apricot cultivars from outside the region. The popularity of Ladakhi apricot remains restricted to the region because of limited production [3]. The local Ladakhi apricot, colloquially known as *Chuli* has been classified into two distinct groups based on kernel taste. The *Khante* being the one with the bitter kernel, and the *Ngarmo* consists of the fruit with sweet kernel [8]. *Ngarmo* is further categorized into two groups on the bases of stone colour. Fruit with white coloured stone is locally called *Raktsey Karpo*, while fruit with the sweet kernel and brown coloured stone are known as *Nyarmo*. Fruits that are large in size are called *Chenmo* meaning large, while those with small size are called *Chun* meaning small. Apricots with white coloured stone are unique to this region and are always linked to the sweet kernel, high TSS and bright coloured fruits. Fruits of *Raktsey Karpo* are known for their sweetness and used for fresh consumption [3].

Figure 1.2: Fruit stone of apricots of trans-Himalayan Ladakh with white (a) and brown (b) colour

1.3 Traditional and economic importance

Apricot has multiple uses. No part of the fruit goes waste. Apricots is found most suitable for human consumption either in the form of fresh and dried, or as various confectionery products such as jam, juice, puree, jelly, marmalade, frozen dessert, paste, ice cream, wine, liquor, and vinegar [9], [10], [11], [12] . The sweet kernel is used for human consumption and also as a good substitute for almonds and nuts. The bitter kernel is used to extract oil for cosmetic products, soap composition and pharmaceutical industry [8], [13]. In some regions of Asia, apricot is grown primarily for the edible seed and oil, which are more consequential than the fruit [5].

In the Ladakh region of Jammu & Kashmir, apricot is directly associated with the traditions and cultures of the region. It is one of the major sources of livelihood. Dried apricot is the only horticultural product that is in high demand within and outside Ladakh region. Dried fruit is rehydrated by hot water overnight and is served with bread. The sweet kernel is dried and the powder is mixed with barley flour and is served in weddings as well as during field work. Apricot oil also has religious importance and is used to light lamps in monasteries. The oil is also used in the traditional *Amchi* system of medicine. Bitter kernel oil is used as hair oil and is believed to control hair fall and dandruff. It is also found to prevent joint pain and dryness of skin [8]. Lakdan et al. [14] estimated an overall gross return of Rs 1.6 lakh and net return of Rs. 1.32 lakh from 100 apricot trees in Ladakh.

1.4 Nutritive value

Apricot is a nutritious fruit. The nutritive value of fruit (fresh and dried) as per the USDA nutrient database and other studies [15], [16] is shown in Table 1.1 and that of the kernel is shown in Table 1.2.

1.5 Fruit quality and consumers preferences

Fruit quality is the major concern for acceptability of apricot cultivars by the buyers, particularly as concerned with the current situation the high competition requirement in the market with the existence of many modern cultivars, fruits, and other food [17]. Fruit quality embraces sensory attributes, nutritive values, mechanical properties, functional properties and chemical constituents [18], [19], [20]. Fruit choices made by consumers are predominantly determined by attributes such as colour, shape, size and external defects. Consumer’s interest is mainly focused on juiciness, aroma, and flavor of apricot fruit, especially on the sugar content which is the most considerable quality [17], [21]. These quality attributes are strongly linked with the variety and ripening stages of the fruit [22]. Visual appeal is also one of the major quality attributes of fruit which is most demanded in the fresh market [23], and consumers are attracted to bright coloured apricots [24]. Therefore, new apricot genotypes and cultivars with high fruit quality traits are needed for consumers’ satisfaction [17]. Lack of awareness regarding perceived apricot fruit quality is also another weak point. When compared with apples, where consumers are well known with varieties of fruit, a survey conducted in France demonstrates that about 81% of the questioners were not able to identify a single variety of apricots. They considered fresh apricots as a generic product [24]. Since fresh apricot fruit are available for fresh consumption in the market for a very short time, it is very difficult for consumers to make up a sound picture of quality fruit based on particular phenotypic traits as for apples [30].

Numerous pomological and sensory traits such as fruit size, colour, firmness, taste, aroma, and texture determine fruit quality [31], [32].The sensorial properties of apricots are influenced by organic acids, sugars, size, colour, texture and volatile compounds content [33]. Reports with analytical data for quality control of apricots are available [34], [35].

Table 1.1: Nutritional value of apricot (fresh and dried) as per USDA

Nutrients	Unit	Value/100gm		Nutrients	Unit	Value/100gm	
		Fresh apricot	Dried Apricot			Fresh apricot	Dried Apricot
Proximates				Beta carotene	µg	1094	2163
Water	g	86.35	30.89	Total choline	mg	2.8	13.9
Protein	g	1.4	3.39	Folate, total	µg	9.0	10.0
Energy	kcal	48	241	Niacin	mg	0.6	2.589
Total lipid (fat)	g	0.39	0.51	Pantothenic acid	mg	0.24	0.516
Ash	g	0.75	2.57	Riboflavin	mg	0.04	0.074
Total dietary, fiber	g	2.00	7.36	Thiamin	mg	0.03	0.015
Carbohydrate	g	11.12	62.64	Lipids (Fatty acids)			
Glucose	g	2.37	33.08	Total saturated	g	0.027	0.017
Fructose	g	0.94	12.47	Total monounsaturated	g	0.17	0.74
Sucrose	g	5.87	7.89	Total polyunsaturated	g	0.077	0.074
Total sugars	g	9.24	53.44	Amino Acids			
Minerals				Tryptophan	g	0.015	0.016
Calcium, Ca	mg	13.0	55.0	Threonine	g	0.047	0.073
Copper, Cu	mg	0.078	0.34	Isoleucine	g	0.041	0.063
Iron, Fe	mg	0.39	2.66	Leucine	g	0.077	0.105
Magnesium, Mg	mg	10.0	32.0	Lysine	g	0.097	0.083
Manganese, Mn	mg	0.077	0.24	Methionine	g	0.006	0.015
Phosphorus, P	mg	23.0	72.0	Cystine	g	0.003	0.019
Potassium, K	mg	259	1162	Phenylalanine	g	0.052	0.062
Sodium, Na	mg	1.0	10.0	Tyrosine	g	0.029	0.039
Selenium, Se	µg	0.1	2.2	Valine	g	0.047	0.078
Zinc, Zn	mg	0.2	0.39	Arginine	g	0.045	0.066
Vitamins				Histidine	g	0.027	0.047
Vitamin A, RAE	µg	96	180	Alanine	g	0.068	0.11
Vitamin A, IU	iu	1926	3604	Aspartic acid	g	0.314	0.937
Vitamin B-6	mg	0.054	0.143	Glutamic acid	g	0.157	0.188
Vitamin C	mg	10.0	1.0	Glycine	g	0.04	0.07
Vitamin E (alpha-tocopherol)	mg	0.89	4.33	Proline	g	0.101	0.821
Vitamin K (phylloquinone)	µg	3.3	3.1	Serine	g	0.083	0.087

Table 1.2: Nutritional value of apricot kernel

Nutrient	Unit	Value/100gm	Reference
Proximates			
Energy	Kcal	884	USDA [25]
Total lipid (fat)	g	100.0	
Protein	g	14.1-45.4	Alpaslan and Hayta [26]
Oil content	g	27.7-66.7	
Ash content	g	1.7-2.9	
Moisture	g	6.86	Bachheti et al. [27]
Fiber	g	1.94	
Carbohydrates	g	15.61	
Minerals			
Calcium (Ca)	mg	1.8-2.4	Normakhmatov et al. [28] and
Iron (Fe)	mg	2.14-2.82	Pala et al. [29]
Magnesium (Mg)	mg	113-290	
Potassium (K)	mg	473-570	
Sodium (Na)	mg	35.2-36.8	
Zink (Zn)	mg	3.15-2.33	
Nickel (Ni)	mg	0.14	Normakhmatov et al. [28]
Manganese (Mn)	mg	0.48	
Vitamin			
Thiamin	mg	0.12-0.38	Alpaslan and Hayta [26]
Riboflavin	mg	0.18-0.26	
Niacin	mg	2.03-6.07	
Vitamin C	mg	1.05-2.14	
Vitamin E (alpha-tocopherol)	mg	4.0	USDA [25]
Lipids (Fatty acids)			
Total saturated	g	6.30	USDA [25]
Total monosaturated	g	60.0	
Total polysaturated	g	29.3	

Azodaanlou et al. [36] proposed a model for quality assessment on the basis of TSS and total volatile compounds which provide limited information for good quality apricots. Quality parameters of apricots may not be autonomous to one another, and therefore interrelationships among these quality, parameters need to be studied.

Apart from fruit quality, consumers often criticize the organoleptic quality of apricot. Consumers are concern about the increase in poor taste of fresh apricots [37], especially the lack of sweetness in purchased apricots [38]. Sub-optimal fruit quality in terms of fruit aroma is frequent at the retail outlets [39]. Apricot fruit has limited post-harvest life because of high moisture content, so fresh apricots are available for sale for a very short period [40]. It is, therefore, hard for consumers to make up a strong image of high-quality apricot fruits. Therefore, there is a need to develop an easily identifiable phenotype that can be associated with quality apricots.

1.6 Sugar profiling and content

Sugar plays a fundamental role in plant metabolism, catabolism, signaling network, cell division, transportation of carbon and energy, regulators for gene expression and amalgamation of many complex molecules in plant [41]. Besides, it also plays an important role in induced stress-responsive genes, which alter the metabolic pathway modules of the plant during exposure to different environmental conditions [42]. Apricot fruit has high sugar content and has a perfect balance between organic acids and sugar content. This combination is combined with the rich aroma of fruit [43]. Taste of fruit is a desirable trait that contributes to the quality of fruit and is a predominant factor in breeding programs. Taste of fruit is determined by various forms of organic acids and soluble sugar content [44]. In apricots, the main contributor to fruit sweetness is fructose and sucrose. It also contributes to consumer satisfaction and sensory quality of fruit [45]. Sucrose is mostly reported as a major sugar present in apricots which is succeeded by glucose, fructose and sorbitol [37], [39], [45], [46]. In few studies higher glucose level than sucrose content [47]; and lower fructose [39] and glucose level [48] than sorbitol have also been documented. Akin et al. [48] reported sorbitol content as a major sugar in some varieties of apricot cultivars. The % age of these four major soluble sugars varied significantly in apricots grown in different parts of the world (glucose: 5.3-28.1%; sucrose: 17.6-81.8%; fructose: 1.9-16.6%; sorbitol: 0.3-32.5%). In apricot kernels, the most common sugars are sucrose, glucose, and fructose. Femenia et al. [49] reported that bitter apricot kernels contain higher sugar as compare to sweet kernels. The difference in the individual levels of sugar could be the effect of both environmental conditions and the genotypic factor. It has been reported that individual sugar patterns is under the genetic control in apricots [50]. However, little is known on the effect of the environmental component on apricot fruit and kernel and on its sugar profiles.

1.7 Amygdalin

Amygdalin is a natural cyanogenic glucoside which gives a bitter taste to the kernel. Multiple cases of poisoning as a result of the consumption of bitter apricot kernel have been reported [51], [52]. It is reported that if the kernel is consumed directly without chewing then less amount of cyanide is released, than if the kernel is chewed completely [53]. Once chewed, the kernel released cyanide which reacts in small intestine under the alkaline environment, with the process of emulsification it gets quickly absorbed and circulates in the body. Cyanide causes anoxia which blocks the cytochrome oxidase to the tissues at the cellular level due to which anaerobic metabolism occurs and causes hypoxia and lactic acid is produced [51]. Amygdalin has been mistaken for laetrile. Both laetrile and amygdalin are promoted as vitamin B17, which is used for cancer treatment, but these are not really a vitamin [54]. The disputable utilization of amygdalin in the treatment of cancer by numerous alternative therapists is well known [55]. However, it is completely ineffective and toxic [56] and known to cause cyanide poisoning [57]. A systematic review concluded that there is no adequate data from any controlled clinical trials which support that amygdalin has any advantageous role for cancer treatment [58], [59]. Therefore, the presence of amygdalin content in the apricot kernel is considered as an undesirable character for human consumption. It is well documented that the amygdalin level in the bitter kernel is significantly greater than that of the sweet kernel [49], [60], [61]. Within the sweet kernel it ranged from less than 0.08 to 15.84 $mg.g^{-1}$ DW [60], [61]. Similarly, it ranged from 13.96 to 55 $mg.g^{-1}$ DW in bitter apricot kernel [49], [61]. The level of amygdalin differed highly in apricot kernel documented from many apricot growing locations throughout the world. The difference in the levels of amygdalin could be the result of both environmental and genotypic factors, but no literature is available about the effect of environmental conditions on amygdalin content.

1.8 Genetic Diversity

Genetic diversity (GD) is the core of biological diversity. The presence of plant genetic diversity is essential to ensure its long-term adaptation to the changing ecological environment [62]. Abundant plant genetic diversity can provide a wide range of genetic backgrounds for crop genetics and breeding research [63]. The assessment of the GD of crop germplasm is very important for the protection of endangered resources and sustainable use of the resources.

Central Asia is the primary and oldest source of genetically diverse apricot germplasm in central Asian accessions. In order to perform an assessment of the GD of the germplasm of cultivated plants, both in collections and in the field, the use of molecular markers has become an essential tool. The analysis of DNA with these molecular marker tools allows resolving the identification of genotypes which is impossible to obtain with morphological observation alone. There are several molecular techniques which are not affected by environmental changes, including inter-simple sequence repeats (ISSRs), sequence-related amplified polymorphism (SRAPs), simple sequences repeats (SSRs) and amplified fragment length polymorphism (AFLP). These can screen the whole genome to describe the diversity and genetic characterization of apricot germplasm worldwide. However, the genetic diversity of apricots of trans-Himalaya has not been studied in detail.

Thus, considering the above research gaps in apricots, the present study has been conducted with the following objectives:

1. Fruit quality, consumer perception and quality assessment for fresh apricots of Ladakh

2. Change in phenology and fruit quality of fresh apricot along an altitudinal gradient in trans-Himalaya

3. Altitudinal effect on sugar content and sugar profile in dried apricots

4. Effect of altitude and seed phenotypic characters on amygdalin and sugar content in apricot kernel

5. Morphological and SRAP markers based genetic diversity studies of apricots of trans-Himalaya