CHAPTER 3

CHANGE IN PHENOLOGY AND FRUIT QUALITY OF FRESH APRICOT ALONG AN ALTITUDINAL GRADIENT IN TRANS-HIMALAYA

Abstract

Consumer concern about the poor taste of fresh apricots is increasing and knowledge about the more suitable production requirement is essential. Genetic component influencing apricots quality is well known. However, there is limited information on the environmental effect on fruit quality. Therefore, this investigation aimed at studying the influence of elevation on phenological and fruit quality characters of apricot genotypes. Fruits from 162 trees were sampled from nine villages located at an elevation ranging from 3006 to 3346 meter asl in Ladakh. The altitude had a significant influence on the date of flowering, fruit weight, moisture, and TSS content. For every 100 meter rise in elevation, flowering and fruit ripening delayed by 3.3 and 7.1 days, respectively. An inverse relationship between fruit weight and elevation (R^2 = 0.310) was observed. The fruit weight decrease by 0.5 gm for every 100 meter increase in elevation. Fruit moisture content decreased significantly with increase in elevation (R^2 = 0.585). The decrease in moisture content was 1.9% for every 100 meter rise in elevation. Increase in elevation had a linear relationship with fruit TSS content (R^2 = 0.726). The fruit TSS increased by 1.2ºBrix for every 100 meter rise in elevation. Knowledge from the present study on the impact of altitude on fruit quality characters suggests guidance on selection of orchard site for improving apricot fruit quality.

3.1 Introduction

Trials conducted around the world have shown that the genetic factor determines quality characters of apricot fruits. As for the environmental factor, limited numbers of studies on a few cultivars are available in the literature on the variability in fruit quality traits. When Hasenbey and Şekerpare cultivars were grown at two elevations (850-1200; 1150-1600 meter asl), the fruit TSS increases and fruit size decreases at a higher elevation [73]. When three apricot cultivars were grown at 731, 855 and 1115 meter elevation, a linear relation was not observed between rising elevation and fruit quality traits such as TSS and fruit weight [74]. Contrasting observations have been recorded in other fruits on influence of elevation on the fruit quality. Because of the contrasting reports from limited research trials, investigations involving a bigger number of genotypes across different elevation are required to have a clearer understanding of the elevation effects on apricot fruit quality characters. While most of the studied were conducted below 1500 meter, there is little information from regions above 3000 meter. This knowledge is vital since it suggests guidance on selection of orchard site for improving apricot quality.

3.2 Materials and methods

3.2.1 Study sites

Apricots were collected from nine isolated villages spread across Ladakh region. The villages were located at an altitude ranging from 3006 to 3346 meter asl (Table 3.1)

3.2.2 Phenological, pomological and fruit quality traits

Date of flowering was determined when 50% of the floral buds attain full bloom stage. It was expressed in Julian days i.e. natural days from 1st January. Date of harvesting the fruit from each tree was established on the basis of fruit colour, firmness, and taste. Fruit samples (50 fruits per tree) were randomly handpicked at eating maturity stage. Standard pomological and fruit quality traits were determined on the date of harvest (Table 3.2). Stone and fruit weight was measured with a balance with 0.001 g accuracy. TSS was determined with the refractometer and values were corrected at 20ºC. Oven drying method was used to determine the moisture content of the fruit and expressed as percentage fresh weight (AOAC 1990).

Table 3.1: Geographical locations and sampling site of apricots in trans-Himalaya

Sampling localities	Population ID	Latitude (N)	Longitude (E)	Altitude (m) (asl)	Sample size
Takmachik	TAK	34° 23.522”	76° 45.981”	3006	18
Domkhar	DOM	34° 23.522”	76° 45.984”	3008	18
Khalsi	KLS	34° 19.166”	76° 52.564”	3011	18
Nurla	NUR	34° 17.941’	76° 59.490”	3046	18
Saspol	SPL	34° 14.251”	77° 10.194”	3116	18
Nimmu	NMU	34° 11.357”	77° 20.437”	3190	18
Tamisgam	TSG	34° 19.444”	76° 59.463”	3241	18
Tia Khaling	TIA	34° 19.979”	76° 58.685”	3311	18
Leh	LEH	34° 08.267”	77° 34.378”	3346	18

3.2.3 Statistical analysis

Data was recorded in triplicate. Each replicate consisted of three fruits. The results were expressed as the mean ± standard deviation using SPSS 16 statistical tool and MS Excel 2007. ANOVA and post hoc analysis with 2-sided Tukey’s HSD at $p \leq 0.05$ level were performed. Pearson’s correlation analysis was done to find a correlation between the different variables.

3.3 Results and discussion

3.3.1 Altitude effect on flowering phenology and fruit ripening date

Altitude significantly affects flowering phenology (Table 3.2). The Linear relationship between date of flowering and the rise in elevation was observed (R^2=0.914) (Figure 3.1a). For every 100 meter increase elevation, flowering was delayed by 3.3 days. Flowering dates showed significant variability and it ranged from 104.0 at 3006 meters to 116 Julian days at 3346 meter elevation (Figure 3.2). Similarly, a linear relationship between harvest date and increasing elevation was seen (R^2 = 0.820) (Figure 3.1b). For every 100 meter rise in elevation, fruit ripening delayed by 7.1 days.

Altitude had a marked influence on flowering phenology. Delay in date of flowering was observed with increasing altitude. Flowering delayed by 3.3 days for every 100 meter increase in elevation. Flowering dates showed significant variability and ranged from averaged 104.0 at 3006 m to 116 Julian days at 3346 m elevation. Delay in flowering in higher altitude regions may be associated with decreasing temperature. Significant differences in flowering dates in apricot have been published from different regions. Apricot blooming dates in Spain and Italy varied from 25 to 80 Julian days [75], 79.9 to 88.7 Julian days in Serbia [76] and 111 to 114 Julian days in Ladakh [3]. Results of the current study suggested that differences in date of flowering are largely due to environmental factors associated with altitude. Late flowering is a vital character to protect the flower from chilling effect, and hence, a desirable character in high altitude regions. Similarly, a linear relationship between harvest date and rising in elevation was seen (R^2 = 0.820). For every 100 meter rise in elevation, fruit ripening delayed by 7.1 days. Apricots from different regions are known for marked differences in date of fruit ripening. Apricots are harvested in May to June in Greece and America [46] while selections and cultivars in Spain are harvested in mid-May to late June [17]. Fruits attain maturity in late June and early July in Anatolia, Turkey [67] while fruit from Lake Van Region in Turkey attains maturity between late July to early August [77]. In trans-Himalayan Ladakh, fruits attain maturity in August and early September [3]. Knowledge from the present study highlighted that difference in apricot fruit harvesting dates from different apricot growing regions is primarily due to environmental effects.

3.3.2 Altitude effects on pomological traits

Pomological attributes of 162 apricot genotypes collected from nine locations are presented in Table 3.2. Fruit weight ranged from 5.3-52.5 g. We have seen the opposite relationship between altitude and fruit weight (R^2=0.310). For every 100 meter rise in elevation the fruit weight decrease by 0.5 gm. Fruit moisture content decreased significantly with increase in elevation (R^2=0.585) (Figure 3.1c). The decrease in moisture content was 1.9% for every 100 meter increase in elevation. Blush area and seed dimensional properties showed an opposite relationship with altitude, but not significant.

Marked variability in fruit weight was observed among the 162 genotypes, ranging from 5.3-52.5 g. In comparison, fruit weight of 24.2 to 48.3 g has been reported among apricots of the Lake Van region [77]. A much higher fruit weight ranging from 49.1 to 81.5 g has been reported in apricot genotypes from Central Serbia [68].

Table 3.2: Morphometric and pomological characteristics of apricot fruits of trans-Himalaya

Location	FB (JD)	FrW (g)	SW (g)	FW (g)	TSS (^{0}Brix)	MC (%)	BA (mm)^{2}	FrL (mm)	FrWd (mm)	SL (mm)	SWd (mm)	ST (mm)	SCT (mm)
TAK	104.1 ±1.6^{b}	18.1 ±8.5^{d}	2.0 ±0.5^{d}	16.0 ±8.2^{c}	19.1 ±4.7^{ab}	73.7 ±5.8^{de}	163.4 ±294.8^{ab}	30.1 ±5.7^{cd}	32.1 ±5.0^{c}	21.1 ±2.3^{cd}	18.0 ±2.2^{c}	12.2 ±2.1^{b}	1.5 ±0.3^{a}
DOM	105. 8±3.1^{d}	17.8 ±5.4^{cd}	1.9 ±0.4^{b-d}	15.9 ±5.1^{c}	17.8 ±3.7^{a}	74.8 ±4.2^{e}	225.7 ±218.7^{ab}	28.0 ±4.0^{a-c}	30.2 ±4.0^{a-c}	19.5 ±2.0^{ab}	16.5 ±1.9^{ab}	11.5 ±1.7^{ab}	1.5 ±0.3^{a}
KLS	103.5 ±1.4^{a}	16.8 ±3.6^{b-d}	1.9 ±0.4^{cd}	14.9 ±3.3^{bc}	19.4 ±5.0^{ab}	73.0 ±3.8^{c-e}	265.6 ±236.2^{b}	30.5 ±3.8^{d}	30.9 ±3.1^{bc}	21.7 ±3.5^{d}	17.2 ±2.8^{a-c}	11.9 ±2.6^{ab}	1.4 ±0.3^{a}
NUR	104.9 ±0.7^{c}	13.8 ±2.0^{a}	1.6 ±0.3^{a}	12.1 ±1.9^{a}	19.6 ±3.5^{a-c}	73.6 ±3.2^{c-e}	238.8 ±217.1^{ab}	27.3 ±1.9^{a}	29.2 ±1.7^{ab}	19.0 ±1.6^{a}	16.9 ±1.4^{a-c}	11.6 ±1.6^{ab}	1.4 ±0.3^{a}
SPL	107.4 ±0.6^{e}	15.7 ±3.5^{a-d}	1.8 ±0.4^{a-d}	13.9 ±3.2^{a-c}	22.3 ±5.2^{cd}	69.8 ±4.8^{b}	182.3 ±192.9^{ab}	27.9 ±2.7^{ab}	30.4 ±2.4^{bc}	19.8 ±1.4^{ab}	17.1 ±1.3^{a-c}	11.6 ±1.6^{ab}	1.4 ±0.3^{a}
NMU	109.6 ±0.7^{f}	14.7 ±4.7^{ab}	1.7 ±0.3^{ab}	13.1 ±4.5^{ab}	21.1 ±4.4^{bc}	71.0 ±3.5^{b-d}	223.5 ±200.9^{ab}	28.1 ±2.8^{a-c}	29.3 ±3.1^{ab}	19.6 ±1.4^{ab}	16.6 ±1.6^{ab}	11.1 ±1.5^{ab}	1.5 ±0.3^{a}
TSG	114.9 ±1.5^{h}	15.3 ±3.9^{a-d}	1.8 ±0.5^{a-c}	13.5 ±3.5^{a-c}	20.5 ±3.4^{a-c}	72.7 ±3.5^{b-e}	230.8 ±237.1^{ab}	28.0 ±2.7^{a-c}	29.3 ±2.2^{ab}	20.2 ±2.4^{a-c}	16.8 ±1.6^{ab}	11.1 ±1.3^{ab}	1.5 ±0.4^{a}
TIA	112.7 ±1.0^{g}	15.3 ±5.1^{a-d}	1.7 ±0.5^{a-c}	13.6 ±4.7^{a-c}	22.3 ±6.0^{cd}	70.5 ±4.0^{bc}	154.6 ±220.8^{ab}	27.7 ±3.5^{a}	28.3 ±3.8^{a}	19.6 ±2.0^{ab}	16.3 ±1.9^{a}	11.1 ±1.7^{a}	1.3 ±0.2^{a}
LEH	116.0 ±1.5^{i}	14.9 ±3.5^{a-c}	1.8 ±0.4^{a-c}	13.2 ±3.3^{ab}	24.3 ±6.2^{d}	63.3 ±10.6^{a}	128.7 ±182.0^{a}	30.0 ±3.6^{b-d}	30.1 ±3.5^{ab}	20.6 ±2.2^{b-d}	17.5 ±2.4^{bc}	11.7 ±1.8^{ab}	1.4 ±0.2^{a}
Average	108.8 ±4.7	15.8 ±4.9	1.8 ±0.4	14.0 ±4.6	20.7 ±5.1	71.4 ±6.2	201.5 ±226.7	28.6 ±3.7	30.0 ±3.5	20.1 ±2.3	17.0 ±2.0	11.5 ±1.8	1.4 ±0.3

Values represented mean ± SD; for each column different lowercase letters indicate significantly differ ($P \le 0.05$) JD: Julian days; FB: date of full bloom; FrW: fruit weight; SW: Seed weight; FW: flesh weight; TSS: total soluble solids; MC: Moisture content; BA: blush area; FrL: fruit length; FrWd: fruit width; SL: seed length; SWd: seed width; ST: seed thickness; SCT: seed coat thickness

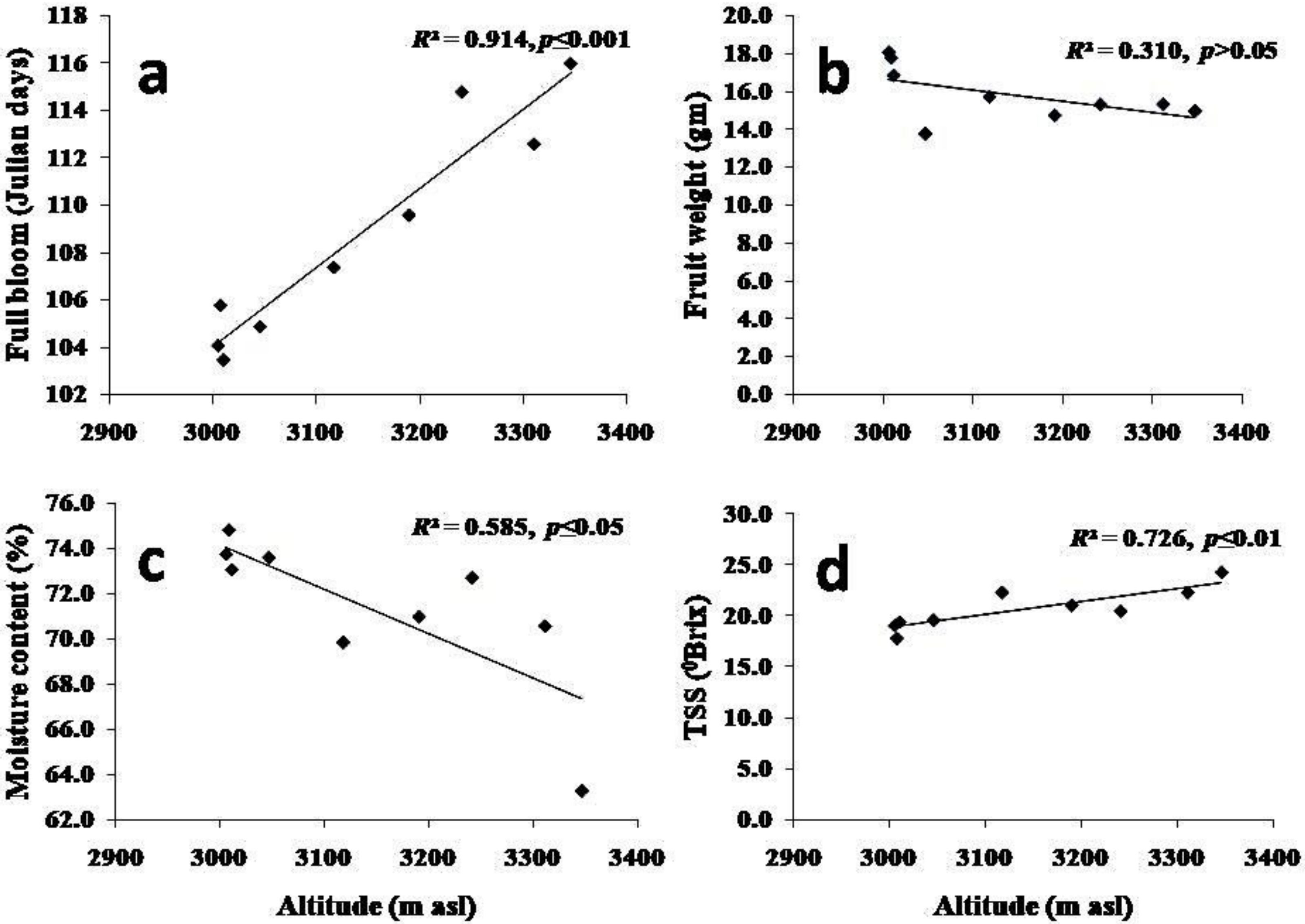

Figure 3.1 Altitudinal variation in apricot (a) flowering; (b) fruit weight; (c) fruit moisture content; (d) fruit TSS in trans-Himalayan region

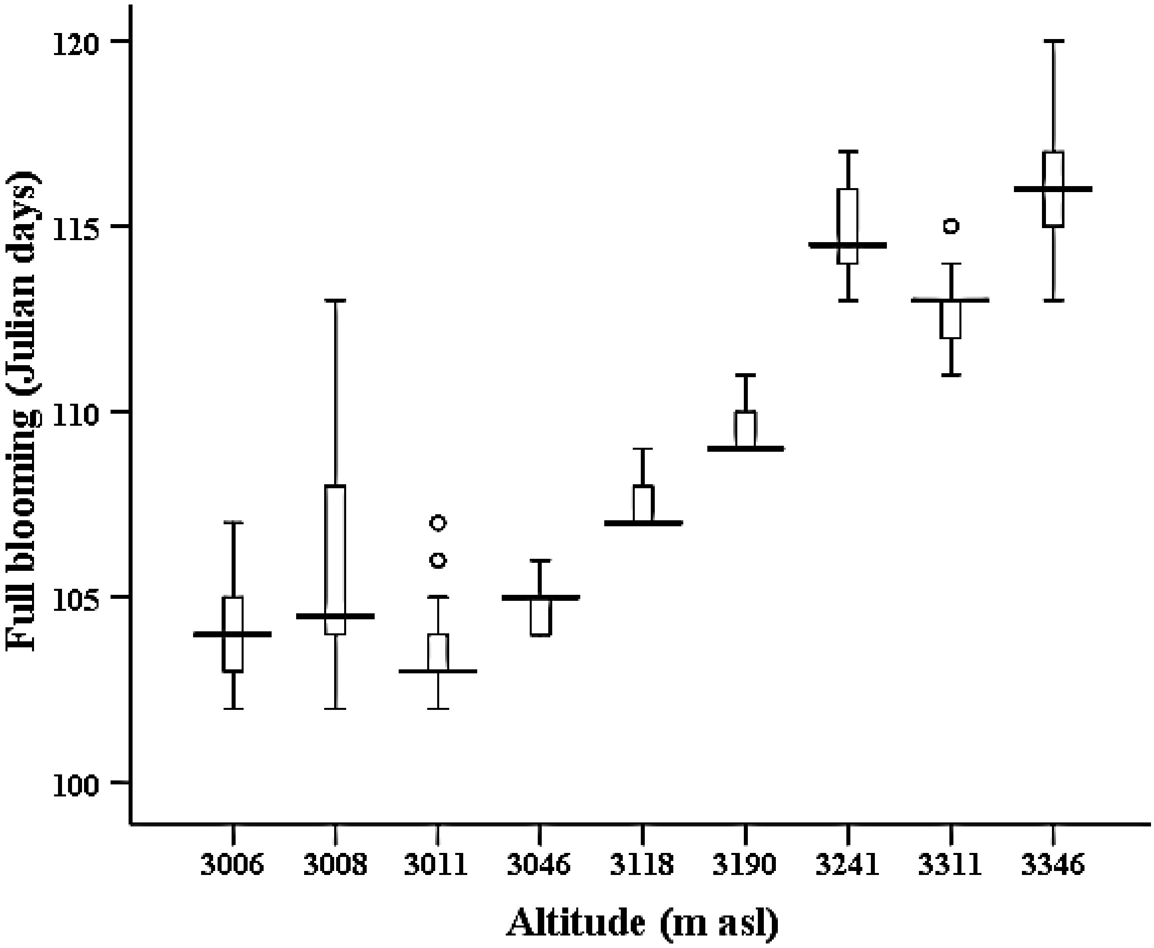

Figure 3.2. Box plot distribution of date of apricot full bloom along altitudinal gradient in trans-Himalayan region. The plot represents the minimum and maximum value (whiskers), the first and third quartile (box), the median (midline).

A much higher fruit weight ranging from 49.1 to 81.5 g has been reported in apricot genotypes from Central Serbia [68]. Twenty one cultivars from Canada, Ukraine, Czech Republic, and the USA ranged between 28.1 to 77.7 g [78]. Single fruit of twenty nine hybrids and cultivars of Greek and American origin weigh 36.5 to 105.3 g [46]. We have seen the opposite relationship between altitude and fruit weight ($R^2 = 0.310$). For every 100 meter rise in elevation the fruit weight decrease by 0.5 gm. When grown in California condition Central Asian apricot germplasm remained small (9.4 g) [39], and thus shows the importance of genotypic factor on fruit size. Wide variability in fruit weight (5.6 to105.3 g) among cultivated apricot is, therefore, the result of both environmental and genotypic factors.

Our data is partly in accordance with the observations made by Olmez et al. [74] who reported that only one out of three apricot cultivars studied showed decreasing fruit size with increasing elevation. However, in the two other cultivars, fruit size increases with increasing elevation from 731 to 855 meter asl and then showed a declining trend when grown at 1115 meter. Our data is in contrast with studied on other fruits such as fig [79] and chestnut [80], [81] where the increase in fruit size was observed with increasing elevation. It is suggested that larger fruit size could be due to antifreeze protein production at the higher elevation [80]. In sweet cherry and mandarin, no relation was found between fruit weight and altitude [82], [83]. Contrasting results in the previous studies could be due to the difference in altitude of studied areas. While most of the studied were conducted below 1500 meter, our study focuses on high altitude regions above 3000 meter asl.

Fruit moisture content showed a decreasing trend with the increase in elevation (R^2=0.585). Fruits of trans-Himalaya have, therefore, lower moisture content as compared to previous reports [69], [84], which may be because of drier climatic conditions in higher elevations. Fruit moisture content is an important factor at commercial maturity stage. Apricots with high moisture content are sensitive to transportation and handling. High moisture content caused fruit to spoil earlier [69]. Blush area and seed dimensional properties showed an opposite relationship with elevation, but not highly significant ($p \leq 0.05$).

3.3.3 Altitude effects on fruit TSS content

Altitude showed a linear relationship with fruit TSS content (R^2=0.726) (Figure 3.1d). The evaluated genotypes showed marked variability in TSS ranging from 10.7-37.6ºBrix with an average of 20.7±5.1 (Figure 3.3). Fruit TSS content increased significantly with an increase in altitude (R^2=0.726). The fruit TSS increased by 1.2ºBrix for every 100 meter increase in elevation. Our result is similar to previous reports on mandarin [83], where high fruit TSS was observed at higher altitude. An opposite relation has been reported when pomegranate was harvested at commercial harvest stage at 222, 662 and 898 meters [85]. Similarly, higher TSS content in persimmon fruits grown at low altitude (229 meter) has been reported that those from a high elevation (770 meters) region [86]. No altitudinal effect on fruit TSS was observed in blueberry [87] and sweet cherry [82].

The evaluated genotypes showed marked variability in TSS content (10.7 to 37.6ºBrix). In comparison, it ranged from 5.7 to 18.9ºBrix in 14 genotypes in Central Serbia [68], 12.7 to 20.0ºBrix among six cultivars in Pakistan [69], 11 to 27ºBrix in 128 apricot types and cultivars in Turkey [67], 10.6 to 16.3ºBrix in 43 genotypes in Spain [17], 9.3 to 18.7ºBrix in 55 cultivars in Spain [66], 8.7 to 22.4ºBrix among 51 genotypes in France [43], 12.3 to

15.8ºBrix in 18 international germplasm collection [70]. The results showed environmental conditions at high altitude are conducive for the production of fruits with high TSS content. Besides the environmental conditions, the genotypic character of Central Asian apricots may also be contributing for higher sugar content. Higher sugar content was recorded when Pakistan origin apricots were grown in California [39]. The result suggested that Central Asian apricot genotypes have innate higher sugar content.

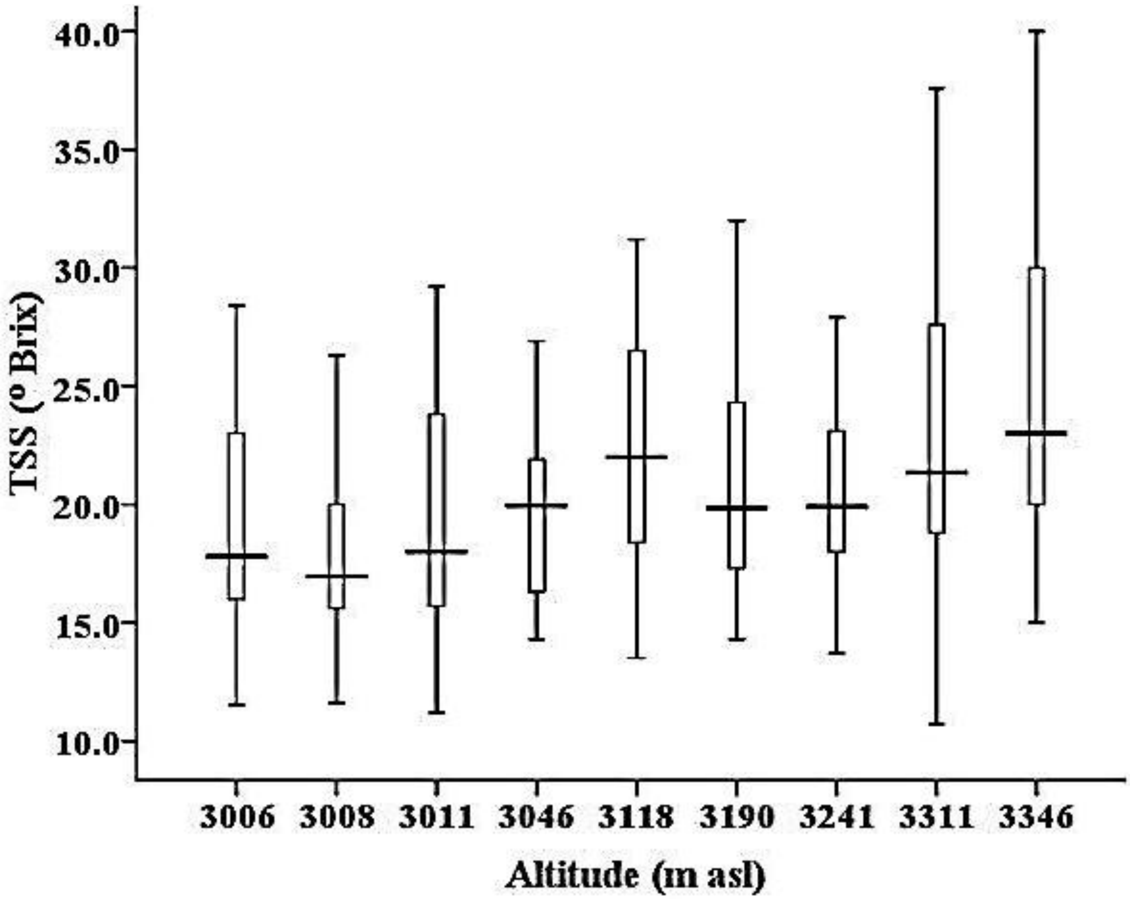

Figure 3.3: Box plot distribution of apricot fruit TSS along altitudinal gradient in trans-Himalayan region. The plot represents the minimum and maximum value (whiskers), the first and third quartile (box), the median (midline).

In the Ladakh region, apricot trees are grown only on irrigated land due to scanty rainfall and high evaporation. Therefore, deficit irrigation is not uncommon in Ladakh, which may be a favorable factor for high TSS content of apricots. Pérez-Pastor et al. [88] have shown apricots with higher TSS when grown under deficit irrigation condition. Dry climatic conditions with low rainfall in high altitude regions appeared to be a favorable factor for fruits with high sugar content. Previous research has reported that fruit TSS is associated with a dry climate in cactus pear [89]. Fruits produced in dry climatic conditions are often sweeter as compared to those produced in irrigated or humid regions [90]. Therefore, dry climatic conditions seem to be one of the important factors responsible for high TSS content of apricot of high altitude regions.

3.3.4 Correlation

Correlations between the variables are presented in Table 3.3. Seed stone colour showed positive correlation with fruit weight (r = 0.530), kernel taste (r = 0.506) and TSS (r = 0.451). Therefore, apricots with white stone are linked with TSS (r = 0.463) and fruit weight (r = 0.426). Flowering date is significantly correlated with harvest date (r = 0.690). TSS is positively correlated with the apricot harvest date (r = 0.324). Late maturing apricots have higher fruit TSS content. Fruit weight showed correlations with TSS (r = 0.177). However, Caliskan et al. [91] did not find correlations between fruit weight and TSS.

Table 3.3: Pearson's correlation coefficients of fruit quality characteristics

	SC	KT	FB	HD	FrW	SW	FW	FW/SW	TSS	MC	BA	FrL	FrWd	SL	SWd	ST	SCT
SC	1	.506**	-.098*	.035	.531**	.375**	.530**	.327**	.451**	-.203**	.312**	.309**	.366**	-.044	.257**	.274**	-.208**
KT		1	-.015	.057	.421**	.228**	.426**	.356**	.463**	-.148**	.371**	.190**	.224**	.001	.046	.067	.136**
FB			1	.690**	-.154**	-.103*	-.154**	-.093*	.218**	-.335**	-.085	-.046	-.175**	-.014	-.063	-.121**	-.010
HD				1	-.120**	-.142**	-.115*	-.006	.324**	-.322**	-.032	-.059	-.210**	-.095*	-.123**	-.114*	-.121**
FrW					1	.694**	.998**	.609**	.177**	.098*	.284**	.673**	.726**	.332**	.426**	.274**	.075
SW						1	.644**	-.123**	.083	-.051	.016	.562**	.561**	.492**	.586**	.379**	.261**
FW							1	.659**	.180**	.109*	.300**	.663**	.719**	.307**	.398**	.256**	.055
FW/SW								1	.194**	.177**	.362**	.321**	.397**	-.076	-.040	-.032	-.161**
TSS									1	-.559**	.132**	.111*	.119**	-.070	.058	.102*	-.113*
MC										1	-.035	-.023	.053	-.031	-.082	-.100*	.059
BA											1	.239**	.268**	.061	.067	.181**	-.176**
FrL												1	.759**	.679**	.574**	.325**	.195**
FrWd													1	.454**	.648**	.416**	.169**
SL														1	.621**	.315**	.334**
SWd															1	.582**	.281**
ST																1	.091*
SCT																	1

* Significant at $p \leq 0.05$; ** Significant at $p \leq 0.01$; SC: Stone colour; KT: kernel taste; FB: date of full bloom; HD: date of harvest; FrW: fruit weight; SW: Seed weight; FW: flesh weight; FW/SW: flesh and seed weight ratio; TSS: total soluble solids; Moisture content; BA: blush area; FrL; fruit length; FrWd; fruit width; SL: seed length; SWd: seed width; ST: seed thickness; SCT: seed coat thickness.

3.4 Conclusion

Knowledge about the effects of environmental conditions on fruit quality is important. The geographic elevation had a significant influence on flowering, fruit weight, moisture, and TSS content. At higher elevation delayed flowering and fruit ripening occurs, and fruit remains smaller with low moisture content. Apricots from higher altitude regions are sweeter with high sugar content as compared to those grown at the lower elevation. Dry climatic conditions with low rainfall appear to be a favorable factor for fruits with high sugar content in high altitude regions.