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Fruit development studies on the pattern of changes in physico-chemical constituents of ber (*Zizyphus mauritiana* Lamk.) cultivars in *Tarai* region

Ankit Kumar, Omveer Singh, Ratna Rai and Karishma Kohli

Abstract
The study on changes in fruit growth and development on eight ber cultivars *viz*., Chhuhara, Chinese, Kalagola, Nazuk, Sanaur-2, Sanaur-4, Umran and ZG-2 was conducted at Horticulture Research Centre, Patharchatta, G. B. Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar, Uttarakhand, India during the season of 2017-18 and 2018-19. The experiment was laid out in two factors Randomized Block Design (RBD) with three replications. Sampling dates and cultivars were considered as the treatments. There were 11 sampling dates commences at 28 days after full bloom (DAFB) to 168 DAFB and observations were taken at biweekly interval. Findings of the study showed a characteristic double sigmoid growth pattern in most of the cultivars which could be divided into four growth phases viz., initial rapid growth of six weeks; lag phase or slow growth of six weeks for seed development; gradual increase in growth for next 6 weeks and later accelerated fruit growth during next four weeks before fruit enter in to its optimum maturity phase. However, these phases varied with the cultivars. TSS increased significantly with advancement of growth and development period and followed the trend of double sigmoid curve. A significant increase in TSS content was witnessed up to 154 DAFB in most of cultivars. The percent titratable acidity showed a downward trend among all cultivars from a maximum of 0.49% at first sampling date to a minimum of 0.07% at last sampling date.

Keywords: Cultivars, sampling dates, fruit development, pattern

Introduction
Ber (*Zizyphus mauritiana* Lamk.) or Indian jujube belongs to the genus Zizyphus of the family Rhamnaceae which has about 50 genera and more than 600 species (Pareek, 1983) [19]. This fruit is very popular among the people of all social strata for its nourishing value and good taste and lower price. Ber is one of the most nutritious fruits with medicinal value. It is one of the richest source of Vitamin C, next to aonla and guava but better than citrus fruits and apple (Bal and Uppal, 1992) [4]. Ber is also designated as "King of Arid fruits" owing to fact that it can be grown in unproductive, waste, marginal or inferior soil with pH as high as 9.0 in arid and semi-arid regions. Maturity is an integral component of quality, especially in the context of commercial maturity (Will *et al*., 1998) [32]. On the other hand, Index is the sign or indication of the readiness of fruits for harvest according to consumers choice (Bautista, 1990) [6]. The time required for ber fruit to develop from fruit set to maturity is dependent on cultivar and location. Fruits that are allowed to ripen on the tree normally have a shorter shelf life and the best results are obtained if they are picked before the onset of ripening (Al-Niami *et al*., 1989) [3]. Immature fruits do not have satisfactory sweetness and taste. Overmature fruits, on the other hand, lose their attractiveness and crispiness and became slimy in texture within a very short time (Pareek, 2001) [18]. Abbas (1997) [1] stated that percentage of titrable acids and total soluble solids are the most important maturity indices for ber fruits, but research in India indicates that the specific gravity of the fruit is more suitable indices (Bal and Uppal, 1992) [4]. Harvesting of fruits at proper stage of maturity is very much important both for maintaining quality and marketing. The studies on changes during growth and development are essential requirement to determine the maturity, harvesting time and method. As the varieties differ in their maturity period it becomes imperative to determine the maturity indices for different cultivars. Maturity indices help in insuring sensory and nutritional quality, ensure an adequate shelf life, facilitate schedule harvest, packing operations and marketing of produce. The present investigations were therefore, carried out to know the precise knowledge and

understanding of the seasonal changes in fruit growth stages and quality characteristics among ber cultivars.

Material and Methods

The present investigation was conducted on existing 40 years old ber orchard at Horticulture Research Centre, Patharchatta, G. B. Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar, Uttarakhand, India during the cropping season of 2017-18 and 2018-19. Eight ber cultivars *viz*., Chhuhara, Chinese, Kalagola, Nazuk, Sanaur-2, Sanaur-4, Umran and ZG-2 were selected for the study. Three trees per cultivar were selected, each of which was considered as a replication. The selected trees were of uniform growth and size, and kept under the uniform cultural practices throughout the experiment during both years. Trees were pruned severely in both years in the 3rd week of May. The experiment was laid out in two factor Randomized Block Design (RBD) with three replications. Fruits were tagged at fruit setting stage and harvested at 28, 42, 56, 70, 84, 98, 112, 126, 140, 154 and 168 days after full bloom (treatments). Sampling dates and cultivars were considered as the treatments. Both fruit growth and quality characteristics were recorded at 14 days (biweekly) interval beginning from 28 days after full bloom (DAFB) to 168 days after full bloom; thus, there were 11 sampling dates/treatment. Twenty fruits at every sampling date from each tree were plucked randomly from all directions of the tree collected in a polyethylene bags and carried to the postharvest laboratory of the Department of Horticulture and analyzed for studying physico-chemical on the day of harvesting. Fruit length and diameter was measured by digital vernier callipers on each sampling date from randomly selected fruits and the average was expressed in centimeters. Total soluble solids of the fruits was observed by using digital hand refractometer (ERMA: 0-32°B) and were expressed in terms of degree brix. Titratable acidity was determined by titrating the sample against 0.1 N NaOH solution using phenolphthalein as an indicator, calculated in terms of citric acid and expressed as per cent on flesh weight basis. The data were analyzed according to the procedure for analysis of two factorial Randomized Block Design (RBD) with three replications as given by Snedecor and Cochran (1987) [29]. The overall significance of differences among the treatments was tested, using critical difference (C.D.) at 5% level of significance.

Result and Discussion

Fruit length (cm)

Data pertaining to fruit length (cm) are presented in Table 1 for the years 2017-18 and 2018-19. The data with respect to fruit length of ber fruits revealed that fruit length of different ber cultivars have been found to be increased with advancement of growth and development period. The data recorded on fruit length showed characteristic of double sigmoid growth pattern. Data showed three stages of fruit length during its growth and development. During season 2017-18, fruit length increased rapidly till 42 days after full bloom (DAFB) in the first phase and thereafter it became stable from 42 days after full bloom (D_2) to 84 days after bloom (D_5) which considered being the lag phase of growth during which seed embryo starts to form and grow while berry growth gets paused. After 5th sampling date (D_5) i.e. 84 DAFB, a 3rd phase of growth with significant increase in fruit length was noticed till 8th sampling date i.e. 126 days after full bloom. Thereafter, a 4th phase of growth with sudden peak of fruits length was noticed on 140 DAFB i.e. 9th sampling date (D_9) except in the cultivars Chinese and Sanaur-4 where this peak was observed on 10th sampling date i.e. 154 DAFB. Similar pattern was also observed in the season 2018-19.

In 2017-18, the maximum (4.85 cm) fruit length was recorded on the last sampling date i.e., 168 DAFB, which was found statistically *at par* with 10th sampling date (4.83 cm). The maximum (4.85 cm) fruit length was recorded in Umran which was statistically *at par* with the cultivar Sanaur-2 (4.75 cm) and significantly higher than other cultivars. Minimum fruit length (3.16 cm) was observed in the cultivar ZG-2 at 154 DAFB which was found statistically *at par* with 9th sampling date i.e. 140th DAFB. In 2018-19, the maximum (4.95 cm) fruit length was also recorded in Umran followed by Sanaur-2 (4.86 cm) and the minimum (3.48 cm) in Chinese followed by Chhuhara (3.55 cm) at 168 DAFB. These values were *at par* with 154 DAFB. At 154 DAFB, fruiting season was over in Nazuk and ZG-2 cultivars.

Pooled analysis of data showed similar trend in increase of fruit length. Maximum (4.90 cm) fruit length was recorded on the last sampling date i.e. 168 DAFB which was found statistically *at par* with fruit length (4.87 cm) recorded at 154 DAFB. At 154 DAFB, maximum (4.87 cm) fruit length was recorded in Umran followed by Sanaur-2 (4.77 cm) while minimum (3.22 cm) was observed in ZG-2. At 154 DAFB, fruiting season was over in Nazuk and ZG-2 cultivars. At last sampling date i.e. 168 DAFB, Umran recorded the maximum (4.90 cm) fruit length followed by Sanaur-2 (4.81 cm) and the minimum (3.42 cm) in Chinese followed by Chhuhara (3.40 cm). These results are similar to the report of Sahu *et al*. (2019) [25], Pareek (2001) [18], Kumar *et al.* (1987) [13], Kundi *et al.* (1989) [14], Faroda (1996) [8], Akhundova and Agaev (1989) [2], Reddy *et al*. (1998) [24], Ram *et al.* (2008) [22] in ber. Rapid increase in fruit length during initial stage could be due to fast cell differentiation and cell enlargement initially followed by slow rate (Ram *et al*., 1983) [21]. Growth is a quantitative process which results in an increase of fruit length (Fleancu, 2007) [9]. Murrinie *et al*. (2017) [16] reported that the increase in fruit size of wood apple that occurred during the process of growth and development of the fruit was caused by division and cell enlargement. Lodh and Pantastico (1989) [15] reported that the growth began in the form of cell division and enlargement, in which cell division is a major factor in the enlargement and continuing for the fruit on the tree. Hossain *et al*. (2016) [11] reported that in sapota fruit length was expanded with time probably due to increase in number of cells as well as cell expansion.

Table 1: Fruit length pattern of developing fruits of ber cultivars at biweekly interval

Treatments		2017-18								
		Chhuhara (C_1)	Chinese (C_2)	Kalagola (C_3)	Nazuk (C_4)	Sanaur-2 (C_5)	Sanaur-4 (C_6)	Umran (C_7)	ZG-2 (C_8)	Mean
28	D_1	1.60	1.30	1.90	2.11	1.73	2.17	1.90	1.61	1.79
42	D_2	2.02	1.93	2.20	2.47	2.51	2.56	2.93	1.91	2.32
56	D_3	2.06	2.08	2.24	2.74	2.64	2.68	3.00	2.33	2.47
70	D_4	2.07	2.15	2.34	2.81	3.07	2.72	3.34	2.72	2.65
84	D_5	2.17	2.32	2.43	2.82	3.11	2.81	3.35	2.81	2.73

98	D_6	2.31	2.75	2.99	3.20	3.68	3.56	3.72	2.92	3.14
112	D_7	2.72	2.80	3.01	3.31	3.71	3.61	3.80	2.94	3.24
126	D_8	2.72	2.85	3.14	3.34	3.75	3.71	3.82	2.96	3.29
140	D_9	3.38	3.05	3.61	3.61	4.37	3.82	4.50	3.14	3.69
154	D_{10}	3.43	3.35	3.62	3.62	4.74	4.31	4.83	3.16	3.88
168	D_{11}	3.44	3.37	3.64	-	4.75	4.33	4.85	-	4.06
Mean		2.54	2.54	2.83	3.00	3.46	3.30	3.64	2.65	

	C. D.	SE(d)	SE(m)
Time Interval (T)	0.045	0.023	0.016
Cultivar (C)	0.038	0.019	0.014
Interaction (T X C)	0.126	0.064	0.045

2018-19

28	D_1	1.45	1.20	2.05	2.10	1.55	2.00	2.10	1.74	1.77
42	D_2	1.92	1.81	2.25	2.65	2.40	2.36	3.10	2.20	2.34
56	D_3	1.98	1.98	2.29	2.75	2.63	2.45	3.20	2.43	2.46
70	D_4	2.10	2.12	2.41	2.85	3.12	2.55	3.30	2.75	2.65
84	D_5	2.25	2.28	2.48	3.02	3.16	2.60	3.56	2.95	2.79
98	D_6	2.34	2.88	3.00	3.12	3.48	3.21	3.65	2.99	3.08
112	D_7	2.82	2.96	3.15	3.42	3.84	3.40	3.75	3.00	3.29
126	D_8	2.94	3.05	3.19	3.48	3.92	3.48	3.88	3.10	3.38
140	D_9	3.48	3.10	3.60	3.54	4.45	3.61	4.55	3.20	3.69
154	D_{10}	3.58	3.45	3.65	3.50	4.80	4.18	4.92	3.28	3.92
168	D_{11}	3.55	3.48	3.68	-	4.86	4.22	4.95	-	4.12
Mean		2.59	2.57	2.89	3.04	3.47	3.10	3.72	2.76	

	C. D.	SE(d)	SE(m)
Time Interval (T)	0.045	0.023	0.016
Cultivar (C)	0.038	0.019	0.014
Interaction (T X C)	0.126	0.064	0.045

Pooled Data

28	D_1	1.52	1.25	1.97	2.10	1.64	2.09	2.00	1.68	1.78
42	D_2	1.97	1.87	2.23	2.56	2.46	2.46	3.02	2.05	2.33
56	D_3	2.02	2.03	2.26	2.75	2.64	2.57	3.10	2.38	2.47
70	D_4	2.08	2.14	2.37	2.83	3.09	2.64	3.32	2.74	2.65
84	D_5	2.21	2.30	2.45	2.92	3.14	2.71	3.45	2.88	2.76
98	D_6	2.33	2.82	3.00	3.16	3.58	3.38	3.69	2.95	3.11
112	D_7	2.77	2.88	3.08	3.37	3.78	3.51	3.78	2.97	3.27
126	D_8	2.83	2.95	3.17	3.41	3.84	3.59	3.85	3.03	3.33
140	D_9	3.43	3.07	3.61	3.57	4.41	3.71	4.52	3.17	3.69
154	D_{10}	3.51	3.40	3.63	3.56	4.77	4.25	4.87	3.22	3.90
168	D_{11}	3.50	3.42	3.66	-	4.81	4.28	4.90	-	4.09
Mean		2.56	2.56	2.86	3.02	3.47	3.20	3.68	2.70	

	C. D.	SE(d)	SE(m)
Time Interval (T)	0.032	0.016	0.012
Cultivar (C)	0.028	0.014	0.01
Interaction (T X C)	0.092	0.046	0.033

Fruit diameter (cm)

Data with respect to fruit diameter (cm) pattern in developing ber fruits are presented in Table 2 for both the years 2017-18 and 2018-19. The data pertaining to the fruit diameter of ber fruits revealed fruit diameter of different ber cultivars have been found to be increased with advancement of growth and development period. The data recorded on fruit diameter showed characteristic of double sigmoid growth pattern. However, data showed different pattern of growth in fruit diameter in most of cultivars during its growth and development. During season 2017-18, fruit diameter in the cultivars Chhuhara, Chinese and Kalagola increased significantly till 42 days after full bloom (DAFB) in the first phase and thereafter it was become stable from 42 days after full bloom (D_2) to 70 days after bloom (D_5) which considered being the lag phase or II phase at which berry growth ceases and seed embryo start to form and grow. After 4th sampling date (D_5) i.e., 70 DAFB, a 3rd phase of growth with significant increase in fruit diameter was noticed till 6th sampling date i.e. 98 DAFB and then it became stable till 126th DAFB i.e. 8th sampling date. Thereafter, a 4th phase of growth with sudden peak in fruits diameter was noticed on 140 DAFB i.e. 9th sampling date (D_9).

However, this growth pattern was somewhat different in the cultivars Nazuk, Sanaur-2, Sanaur-4, Umran and ZG-2. In Nazuk, continuous increase in fruit diameter was observed up to 56 DAFB i.e. 3rd sampling date, then it became stable up to 5th sampling date i.e. 84 DAFB. Thereafter, a significant increase in growth was occurred till 8th sampling date i.e. 126 DAFB followed by a sudden upsurge in fruit diameter at 140 DAFB which was *at par* with 154 DAFB as the fruits were fully ripened on the tree. Similar pattern was also observed in the season 2018-19 in the cultivar Nazuk. In Sanaur-2, continuous increase in fruit diameter was observed up to 56 DAFB i.e. 3rd sampling date, then there was upsurge at 70 DAFB i.e. 4th sampling date and became stable for next 14 days i.e. 84 DAFB. Again an upsurge in fruit diameter was taken place at 98 DAFB which again stable up to 112 DAFB. Thereafter, a steady increasing pattern in fruit diameter was observed from 112 DAFB to 154 DAFB i.e. 10th sampling date which was *at par* with 168 DAFB. Similar pattern in fruit diameter was also observed in the season 2018-19 in Sanaur-2.

In Sanaur-4, a typical double sigmoid developmental pattern in fruit diameter was noticed. A steady increasing pattern in fruit diameter was observed up to 84 DAFB i.e. 5th sampling date followed by slow increasing pattern in fruit diameter up to 112 DAFB i.e. 7th sampling date. Thereafter, a steady increasing pattern in fruit diameter was observed from 112 DAFB to 154 DAFB i.e. 10th sampling date which was *at par* with 168 DAFB, the last sampling date of maturity. Similar pattern in fruit diameter was also observed in 2018-19 fruiting season in Sanaur-2. In Umran, a typical double sigmoid developmental pattern in fruit diameter was also noticed. A fast increase in fruit diameter was observed up to 42 DAFB i.e. 2nd sampling date. However, a negligible growth was taken place in next 14 days i.e. 56 DAFB. Then, a steady increasing pattern in fruit diameter was observed up to 126 DAFB i.e. 8th sampling date. Thereafter, a fast upsurge in fruit diameter was noticed till 154 DAFB which was *at par* with 168 DAFB, the last sampling date of maturity. Similar pattern in fruit diameter was also observed in 2018-19 fruiting season in Umran.

In ZG-2, a single sigmoid type of developmental pattern in fruit diameter was observed. Analysis of data showed that a continuous increasing pattern of fruit diameter was observed up to 70 DAFB i.e. 4th sampling date. Thereafter, a constant increase in fruit size was found up to 140 DAFB i.e. 9th sampling date which was *at par* with 154 DAFB when all the fruits were fully ripened on the tree. In 2017-18, among all cultivar, Umran recorded the maximum (3.63 cm) fruit diameter which was statistically *at par* with Sanaur-2 (3.59 cm) and significantly higher than Kalagola (3.14 cm), Chinese (2.94 cm) and other remaining cultivars. Nazuk recorded the minimum (2.47 cm) fruit diameter which was *at par* with Chhuhara (2.54 cm) followed by ZG-2 (2.85 cm). Most of the cultivars have attained their maximum size at 154 DAFB except Nazuk and ZG-2 who got their maximum size at 140 DAFB and complete their fruiting before 154 DAFB. Similar trend of maximum and minimum diameter of fruit was also observed in 2018-19 fruiting season.

Analysis of pooled data of both seasons revealed similar trends in increase of fruit diameter. Cultivar Umran and Sanaur-2 resulted in maximum (3.68 cm) fruit diameter but significantly higher than Kalagola (3.12 cm) and other cultivars. Minimum (2.48 cm) fruit diameter was also found in Chhuhara followed by Nazuk (2.53 cm). Most of the cultivars have attained their maximum size at 154 DAFB except Nazuk and ZG-2 who got their maximum size at 140 DAFB and complete their fruiting before 154 DAFB. These results are similar to the report of Sahu *et al*. (2019) [25] in ber, Rao and Subramanyam (2010) [23], Brindza *et al.* (2011) [7] and Shukla *et al.* (2012) [26]. Singh *et al*. (2006) [27] reported that growth of passion fruit (Purple and Yellow type) showed the single sigmoid growth curve and slight decline in fruit size at 80 days after fruit set. Rapid increase in fruit breadth during initial stage could be due to fast cell differentiation and cell enlargement initially followed by slow rate (Ram *et al*., 1983) [21]. Hossain *et al*. (2016) [11] reported that in sapota fruit breadth was expanded with time probably due to increase in number of cells as well as cell expansion.

Table 2: Fruit diameter pattern of developing fruits of ber cultivars at biweekly interval

Treatments		2017-18								
		Chhuhara (C_1)	**Chinese (C_2)**	**Kalagola (C_3)**	**Nazuk (C_4)**	**Sanaur-2 (C_5)**	**Sanaur-4 (C_6)**	**Umran (C_7)**	**ZG-2 (C_8)**	**Mean**
28	D_1	0.96	0.86	0.95	0.91	0.95	1.03	1.02	1.01	0.96
42	D_2	1.02	1.33	1.11	1.31	1.36	1.31	1.42	1.71	1.32
56	D_3	1.10	1.37	1.13	1.44	1.51	1.51	1.43	1.94	1.43
70	D_4	1.18	1.41	1.27	1.48	1.92	1.67	1.78	2.43	1.64
84	D_5	1.47	1.71	1.59	1.48	2.01	1.81	1.97	2.51	1.82
98	D_6	1.92	2.17	2.04	1.61	2.44	1.84	2.37	2.54	2.12
112	D_7	1.94	2.19	2.10	1.74	2.54	1.97	2.41	2.67	2.20
126	D_8	1.96	2.20	2.39	1.93	2.91	2.29	2.57	2.69	2.37
140	D_9	2.41	2.63	2.63	2.46	3.23	2.61	3.11	2.82	2.74
154	D_{10}	2.52	2.91	3.12	2.47	3.56	2.94	3.60	2.85	3.00
168	D_{11}	2.54	2.94	3.14	-	3.59	2.97	3.63	-	3.13
Mean		1.73	1.97	1.95	1.68	2.37	2.00	2.30	2.31	
			C. D.			SE(d)			SE(m)	
Time Interval (T)			0.017			0.009			0.006	
Cultivar (C)			0.014			0.007			0.005	
Interaction (T X C)			0.048			0.024			0.017	
2018-19										
28	D_1	0.85	0.91	0.86	0.95	1.00	0.91	1.00	0.97	0.93
42	D_2	0.88	1.20	1.00	1.12	1.21	0.98	1.35	1.41	1.14
56	D_3	1.11	1.32	1.12	1.36	1.54	1.48	1.46	1.54	1.37
70	D_4	1.15	1.36	1.23	1.42	1.65	1.69	1.54	2.10	1.52
84	D_5	1.52	1.56	1.62	1.57	2.10	1.71	2.00	2.31	1.80
98	D_6	1.61	2.10	1.71	1.82	2.52	1.86	2.31	2.52	2.06
112	D_7	1.85	2.27	2.05	1.86	2.70	1.90	2.51	2.72	2.23
126	D_8	2.12	2.63	2.45	2.51	3.20	2.52	3.15	2.81	2.67
140	D_9	2.35	2.86	3.00	2.55	3.65	2.75	3.62	2.85	2.95
154	D_{10}	2.43	2.99	3.07	2.60	3.72	2.87	3.70	2.90	3.04
168	D_{11}	2.45	3.02	3.09	-	3.75	2.90	3.73	-	3.15
Mean		1.67	2.02	1.93	1.77	2.46	1.96	2.40	2.21	
			C. D.			SE(d)			SE(m)	
Time Interval (T)			0.03			0.015			0.011	
Cultivar (C)			0.026			0.013			0.009	
Interaction (T X C)			0.085			0.043			0.03	
Pooled Data										

28	D_1	0.90	0.88	0.90	0.93	0.98	0.97	1.01	0.99	0.95
42	D_2	0.95	1.26	1.06	1.21	1.28	1.14	1.39	1.56	1.23
56	D_3	1.10	1.35	1.12	1.40	1.53	1.50	1.44	1.74	1.40
70	D_4	1.16	1.39	1.25	1.45	1.79	1.68	1.66	2.26	1.58
84	D_5	1.50	1.63	1.61	1.52	2.06	1.76	1.98	2.41	1.81
98	D_6	1.76	2.14	1.87	1.71	2.48	1.85	2.34	2.53	2.09
112	D_7	1.89	2.23	2.08	1.80	2.62	1.94	2.46	2.70	2.22
126	D_8	2.04	2.42	2.42	2.22	3.06	2.40	2.86	2.75	2.52
140	D_9	2.38	2.75	2.81	2.50	3.44	2.68	3.36	2.83	2.85
154	D_{10}	2.48	2.95	3.10	2.53	3.64	2.91	3.65	2.87	3.02
168	D_{11}	2.50	2.97	3.12	-	3.68	2.93	3.68	-	3.14
Mean		1.70	2.00	1.94	1.72	2.41	1.98	2.35	2.26	

	C. D.	SE(d)	SE(m)
Time Interval (T)	0.016	0.008	0.006
Cultivar (C)	0.014	0.007	0.005
Interaction (T X C)	0.047	0.024	0.017

Total soluble solids (°Brix)

Effect of cultivars on total soluble solids (TSS) in developing ber fruits are presented in Table 3 for both the seasons 2017-18 and 2018-19. The data revealed that total soluble solids of fruits of different ber cultivars have been found to be increased with advancement of growth and development period and also followed the trend of double sigmoid curve. TSS increased gradually from 28 days after full bloom to 42 DAFB coinciding with the growth period II which ranged from 42 DAFB to 84 DAFB in most of the cultivars and later showed a steady increase until 126 DAFB. A major increasing drift in TSS was observed between 126 DAFB and 140 DAFB in most of the cultivars except Kalagola, Sanuar-2 and Sanaur-4. In Kalagola, continous increase in TSS was observed from 84 DAFB till the last date of sampling. In Sanaur-2, the first drift was observed between 70 and 84 DAFB and then followed an increasing trend till 140 DAFB. At 140 DAFB again a slight drift was observed. In Sanaur-4 after a first drift between 56 and 84 DAFB, a continuous increasing pattern of TSS was occurred till the last date of sampling. Similar trend was also observed in the fruiting season of 2018-19. Pooled analysis of data revealed similar trend in increase in fruit TSS during both the years of experiment. In all cultivars, the increase in TSS content was witnessed up to 154 DAFB after which the increase in TSS was negligible except in Nazuk and ZG-2 where the increase in titratable acidity content was witnessed up to 140 DAFB due to their optimum time of maturity.

In 2017-18, initially at 28 DAFB the maximum (7.07) total soluble solids were recorded in Umran and the minimum (4.01) in Chhuhara. Later at 154 DAFB the maximum (17.11) TSS was recorded in Chhuhara and the minimum (11.80) in Sanaur-4. At last sampling date of 168 DAFB, Chhuhara recorded the maximum (17.25) TSS followed by Chinese (15.80) and the minimum TSS (13.86) was found in Sanaur-4. In 2018-19, initially the maximum (7.25) TSS was recorded in Umran and the minimum (4.05) in Chhuhara at 28 DAFB. Later the maximum (17.65) total soluble solids were recorded in Chhuhara and the minimum (12.75) in Sanaur-4 at 154 DAFB. At last sampling date i.e. 168 DAFB, Chhuhara recorded the maximum (17.88) total soluble solids followed by Chinese (16.66) and the minimum (12.93) in Sanaur-4. Pooled analysis of data showed that the maximum (7.16) total soluble solids were recorded in Umran and the minimum (4.03) in Chhuhara at 28 DAFB. The maximum (17.38) total soluble solids were recorded in Chhuhara and the minimum (12.28) in Sanaur-4 at 154 DAFB. At last sampling date i.e.168 DAFB, Chhuhara recorded the maximum (17.57) TSS followed by Chinese (16.23) and the minimum (13.39) in Sanaur-4. These results are in agreement with the finding of Pandey and Deen (2018) [17] who reported that total soluble solids content of ber fruit increased continuously with growth period in the cultivar Narendra Ber Selection-1 which might be due to hydrolysis of polysaccharides in to sugar and synthesis of other water soluble. Jawanda and Bal, (1980) [12] also reported rapid increase in T.S.S. towards ripening in different ber cultivars. Similar observation were recorded by Yadav, S. S. (2009) [33] during studies on growth and development of Pevendi ber in Jhansi Uttar Pradesh and showed that total solible solids increased towards maturity. Patel *et al*. (2014) [20] reported that steady rise in TSS of the fruit was observed till final stage of harvesting. The increase in TSS content might be due to degradation of starch during later stage of harvest maturity as well as quick metabolic transformations in soluble compounds, mainly sugars. Similar results are also supported by Teaotia *et al*. (1974) [31], Gupta (1977) [10], Singh *et al*. (1983) [28], Yamdagni *et al*. (1985) [34].

Table 3: Changes in total soluble solids values of developing fruits of ber cultivars at biweekly interval

Treatments		2017-18								
		Chhuhara (C_1)	**Chinese (C_2)**	**Kalagola (C_3)**	**Nazuk (C_4)**	**Sanaur-2 (C_5)**	**Sanaur-4 (C_6)**	**Umran (C_7)**	**ZG-2 (C_8)**	**Mean**
28	D_1	4.01	4.05	4.20	6.05	6.03	4.73	7.07	4.75	5.11
42	D_2	4.04	4.12	4.28	6.33	6.12	5.19	7.35	5.07	5.31
56	D_3	6.05	5.07	4.57	6.63	6.23	5.42	7.43	5.64	5.88
70	D_4	9.23	6.71	7.41	11.04	7.42	8.00	8.05	9.02	8.36
84	D_5	10.07	10.10	10.51	11.55	10.07	10.23	8.90	9.23	10.08
98	D_6	10.27	10.22	11.03	11.67	10.80	10.54	8.98	9.42	10.37
112	D_7	11.03	10.34	11.12	11.77	11.10	10.64	9.10	10.10	10.65
126	D_8	11.15	10.35	11.25	12.03	11.14	11.00	9.50	10.30	10.84
140	D_9	15.07	13.37	11.67	14.42	11.34	11.18	13.05	13.13	12.91
154	D_{10}	17.11	15.55	12.05	15.95	13.95	11.80	14.50	13.90	14.35
168	D_{11}	17.25	15.80	14.20	-	14.80	13.86	15.30	-	15.20

Mean		10.48	9.61	9.30	10.74	9.91	9.33	9.93	9.05	
				C. D.		SE(d)			SE(m)	
Time Interval (T)				0.142		0.072			0.051	
Cultivar (C)				0.121		0.061			0.043	
Interaction (T X C)				0.401		0.203			0.144	
2018-19										
28	D_1	4.05	4.06	4.28	5.26	6.10	4.98	7.25	4.98	5.12
42	D_2	5.28	5.10	4.89	6.88	6.87	5.95	7.68	6.00	6.08
56	D_3	8.25	6.35	7.26	6.90	7.45	8.56	7.72	6.02	7.31
70	D_4	10.75	10.25	9.56	11.24	10.23	9.20	8.00	9.35	9.82
84	D_5	11.10	11.25	11.69	12.45	11.32	11.15	8.84	9.38	10.90
98	D_6	11.85	11.56	12.45	13.10	12.31	12.06	9.02	9.40	11.47
112	D_7	11.95	12.00	12.10	13.52	12.37	12.11	9.13	10.05	11.65
126	D_8	12.04	13.26	12.75	15.00	12.42	12.25	9.48	10.25	12.18
140	D_9	15.22	15.65	12.95	15.85	13.26	12.41	13.43	14.25	14.13
154	D_{10}	17.65	16.35	13.10	16.14	14.00	12.75	14.52	14.55	14.88
168	D_{11}	17.88	16.66	14.35	-	14.85	12.93	15.45	-	15.35
Mean		11.46	11.14	10.49	11.63	11.02	10.40	10.05	9.42	
				C. D.		SE(d)			SE(m)	
Time Interval (T)				0.161		0.082			0.058	
Cultivar (C)				0.138		0.07			0.049	
Interaction (T X C)				0.456		0.231			0.163	
Pooled Data										
28	D_1	4.03	4.05	4.24	5.65	6.07	4.85	7.16	4.86	5.12
42	D_2	4.66	4.61	4.59	6.60	6.49	5.57	7.52	5.54	5.70
56	D_3	7.15	5.71	5.91	6.76	6.84	6.99	7.57	5.83	6.60
70	D_4	9.99	8.48	8.49	11.14	8.82	8.60	8.03	9.19	9.09
84	D_5	10.59	10.67	11.10	12.00	10.69	10.69	8.87	9.31	10.49
98	D_6	11.06	10.89	11.74	12.38	11.56	11.30	9.00	9.41	10.92
112	D_7	11.49	11.17	11.61	12.64	11.73	11.37	9.11	10.08	11.15
126	D_8	11.60	11.81	12.00	13.52	11.79	11.63	9.49	10.28	11.51
140	D_9	15.14	14.51	12.31	15.14	12.30	11.80	13.24	13.69	13.52
154	D_{10}	17.38	15.95	12.57	16.04	13.98	12.28	14.51	14.23	14.62
168	D_{11}	17.57	16.23	14.27	-	14.82	13.39	15.37	-	15.27
Mean		10.97	10.37	9.89	11.18	10.46	9.86	9.99	9.24	

	C. D.	SE(d)	SE(m)
Time Interval (T)	0.112	0.057	0.04
Cultivar (C)	0.096	0.048	0.034
Interaction (T X C)	0.317	0.16	0.113

Titratable acidity (%)

Data on changes in titratable acidity (%) of developing fruits are presented in Table 4 for both the seasons 2017-18 and 2018-19. The data revealed that titratable acidity of fruit of different ber cultivars have been found to be decreased with advancement of growth and development period. Analysis of data of season 2017-18 revealed that titratable acidity showed a downward trend among all the cultivars from maximum of 0.49% at first sampling date to a minimum of 0.07% at last sampling date. In the cultivars Chhuhara, ZG-2 and Sanaur-4 acidity decline occurred in same fashion until 112 DAFB. But a major deflection in acidity decline was found at 126 DAFB and continued till 154 DAFB. Cultivar Kalagola and Sanaur-2 observed this drift at 154 DAFB while cultivar Umran and Nazuk at 140 DAFB and ZG-2 at 98 DAFB. Similar trend was also observed in the fruiting season of 2018-19. Pooled analysis of data also showed similar trend of pH increase during both the years of experiment. In all cultivars, the decrease in acid content was witnessed up to 154 DAFB after which the decrease in titratable acidity was negligible except Nazuk and ZG-2 where the decrease in titratable acidity content was witnessed up to 140 DAFB due to their optimum time of maturity.

In 2017-18 at the first sampling date i.e. 28 DAFB, the maximum titratable acidity (0.49) was recorded in Sanaur-2 while it was found minimum in Umran (0.41). Later at 154 DAFB, the maximum titratable acidity (0.36) was found in Sanaur-2 and minimum (0.07) in ZG-2. At 168 DAFB, the last sampling date Chinese recorded the maximum (0.19) titratable acidity followed by Kalagola and Sanaur-2 (0.17) while it was reduced to minimum (0.12) in Chhuhara. In 2018-19 at the first sampling date i.e. 28 DAFB, the maximum titratable acidity (0.54) was recorded in Sanaur-2 while it was found minimum in Umran (0.45). Later at 154 DAFB, the maximum titratable acidity was reduced to maximum of 0.35% in Sanaur-2 and minimum of 0.08% in ZG-2. At 168 DAFB, the last sampling date Chinese recorded the maximum (0.22) titratable acidity followed by Kalagola (0.21) and Sanaur-2 (0.20) while it was observed minimum (0.14) in Chhuhara. Pooled analysis of data showed that at the first sampling date i.e. 28 DAFB, the maximum titratable acidity (0.51) was recorded in Sanaur-2 while it was found minimum in Umran (0.43). Later at 154 DAFB, the maximum titratable acidity was reduced to maximum of 0.35 % in Sanaur-2 and minimum of 0.08 % in ZG-2. At 168 DAFB, the last sampling date Chinese recorded the maximum (0.21) titratable acidity followed by Kalagola (0.19) and Sanaur-2 (0.19) while it was reduced to minimum (0.13) in Chhuhara. Acidity content of ber fruit was decreased after fruit setting which indicate the accumulation of acid during the initial period at rapid rate.

The results are in conformity to those reported by Teaotia *et al*. (1974) [31] in fruits of ber cv. Bansasi Karka. Bal and Chauhan (1981) [5] also found that ber cv. Sanaura-2 and

Umran acidity content decreased gradually during growth and development. Similarly Soares *et al*. (2007) [30] also observed that titratable acidity increased in the immature and intermediary stage of maturation and decreased in the maturity stage. In general, young fruit contain more acids that declined throughout maturation until ripening due to their conversion to sugars (gluconeogenesis). Patel *et al*. (2014) [20] also reported that increase in acidity might be attributed to increased biosynthesis of organic acid during early stage of fruit growth. The decreased in acidity at later stages of fruit maturity was considered to be due to conversion of organic acids into sugars.

Table 4: Changes in titratable acidity values of developing fruits of ber cultivars at biweekly interval

Treatments		2017-18								
		Chhuhara (C_1)	**Chinese (C_2)**	**Kalagola (C_3)**	**Nazuk (C_4)**	**Sanaur-2 (C_5)**	**Sanaur-4 (C_6)**	**Umran (C_7)**	**ZG-2 (C_8)**	**Mean**
28	D_1	0.45	0.45	0.47	0.45	0.49	0.46	0.41	0.46	0.46
42	D_2	0.44	0.43	0.45	0.43	0.48	0.44	0.36	0.44	0.43
56	D_3	0.42	0.41	0.44	0.41	0.47	0.42	0.35	0.42	0.42
70	D_4	0.41	0.39	0.42	0.37	0.46	0.40	0.33	0.38	0.40
84	D_5	0.40	0.38	0.41	0.36	0.45	0.38	0.31	0.37	0.38
98	D_6	0.38	0.36	0.38	0.35	0.44	0.37	0.28	0.35	0.36
112	D_7	0.35	0.34	0.36	0.33	0.43	0.32	0.27	0.25	0.33
126	D_8	0.25	0.32	0.35	0.32	0.41	0.26	0.25	0.13	0.29
140	D_9	0.18	0.26	0.34	0.25	0.38	0.17	0.22	0.10	0.24
154	D_{10}	0.13	0.22	0.32	0.12	0.36	0.15	0.16	0.07	0.19
168	D_{11}	0.12	0.19	0.17	-	0.17	0.14	0.13	-	0.15
Mean		0.32	0.34	0.38	0.33	0.41	0.32	0.28	0.29	
			C. D.			SE(d)			SE(m)	
Time Interval (T)			0.005			0.002			0.002	
Cultivar (C)			0.004			0.002			0.001	
Interaction (T X C)			0.013			0.007			0.005	
2018-19										
28	D_1	0.49	0.49	0.52	0.49	0.54	0.50	0.45	0.51	0.50
42	D_2	0.48	0.45	0.48	0.45	0.51	0.47	0.41	0.47	0.47
56	D_3	0.45	0.44	0.47	0.43	0.49	0.45	0.38	0.45	0.45
70	D_4	0.43	0.42	0.46	0.41	0.47	0.42	0.37	0.44	0.43
84	D_5	0.40	0.40	0.44	0.37	0.46	0.41	0.33	0.38	0.40
98	D_6	0.38	0.37	0.41	0.37	0.46	0.36	0.29	0.32	0.37
112	D_7	0.31	0.36	0.38	0.35	0.45	0.30	0.28	0.18	0.33
126	D_8	0.23	0.32	0.38	0.33	0.44	0.25	0.27	0.12	0.29
140	D_9	0.17	0.27	0.38	0.20	0.42	0.19	0.20	0.11	0.24
154	D_{10}	0.15	0.24	0.25	0.14	0.35	0.17	0.18	0.08	0.20
168	D_{11}	0.14	0.22	0.21	-	0.20	0.16	0.16	-	0.18
Mean		0.33	0.36	0.40	0.35	0.44	0.33	0.30	0.30	
			C. D.			SE(d)			SE(m)	
Time Interval (T)			0.005			0.003			0.002	
Cultivar (C)			0.005			0.002			0.002	
Interaction (T X C)			0.015			0.008			0.005	
Pooled Data										
28	D_1	0.47	0.47	0.49	0.47	0.51	0.48	0.43	0.49	0.48
42	D_2	0.46	0.44	0.46	0.44	0.50	0.46	0.39	0.45	0.45
56	D_3	0.43	0.42	0.46	0.42	0.48	0.43	0.37	0.44	0.43
70	D_4	0.42	0.40	0.44	0.39	0.46	0.41	0.35	0.41	0.41
84	D_5	0.40	0.39	0.43	0.37	0.46	0.40	0.32	0.38	0.39
98	D_6	0.38	0.36	0.40	0.35	0.45	0.36	0.29	0.33	0.37
112	D_7	0.33	0.35	0.37	0.34	0.44	0.31	0.28	0.22	0.33
126	D_8	0.24	0.32	0.37	0.33	0.42	0.25	0.26	0.12	0.29
140	D_9	0.18	0.26	0.35	0.22	0.40	0.18	0.21	0.11	0.24
154	D_{10}	0.14	0.23	0.29	0.13	0.35	0.16	0.17	0.08	0.19
168	D_{11}	0.13	0.21	0.19	-	0.19	0.15	0.15	-	0.17
Mean		0.33	0.35	0.39	0.34	0.43	0.33	0.29	0.30	
			C. D.			SE(d)			SE(m)	
Time Interval (T)			0.004			0.002			0.002	
Cultivar (C)			0.004			0.002			0.001	
Interaction (T X C)			0.012			0.006			0.004	

Conclusion

From overall observation it was concluded that the pattern of fruit growth in terms of fruit size (Length and diameter) showed a characteristic of sigmoid growth pattern in all the cultivars except ZG-2. Maximum fruit length and diameter was recorded on the last sampling date i.e. 168 DAFB in all the cultivars which were found statistically *at par* with fruit length and diameter recorded at 154 DAFB. TSS increased significantly with advancement of growth and development period and also followed the trend of double sigmoid curve. Highest TSS (17.57) was observed in Chhuhara followed by Chinese (16.23) while it was observed minimum (12.28) in Sanaur-4 at the last harvesting stage. The per cent titratable acidity showed a downward trend among all cultivars from a

maximum of 0.49% at first sampling date to a minimum of 0.07% at last sampling date. Chinese recorded the maximum titratable acidity followed by Kalagola while it was found minimum in Chhuhara.

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